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THE CHANGE IN THE ARTERIAL OXYGEN AND CARBON DIOXIDE TENSION DURING VOLUNTARY HYPERVENTILATION AS A TEST OF LUNG FUNCTION

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PULMONARY resection is being applied in an increasing number of cases with far-advanced pulmonary tuberculosis. In order to avoid postoperative ventilatory insufficiency a new test has been used which includes the determination of the arterial oxygen and carbon dioxide tension at rest and during voluntary hyperventilation. In a group of twenty-one healthy individuals an average increase in the arterial oxygen tension of 23 ± 2.0 mm. Hg and a decrease in arterial carbon dioxide tension of 18.6 ± 2.2 mm. Hg were found. This change in the arterial tension of oxygen and carbon dioxide we believe may be regarded as an expression of the patient's respiratory reserve. The changes in the arterial oxygen and carbon dioxide tension during voluntary hyperventilation in sixty-nine patients with a varying degree of impaired respiratory reserve are reported.

METHOD

A blood sample is taken through an indwelling needle in the femoral artery. After the introduction of the needle a few minutes should be allowed, so that the patient is breathing quietly when the blood is drawn. A few deep breaths may significantly influence the values; however, two patients were asked to hold their breaths for thirty seconds, but no significant change in the arterial oxygen and carbon dioxide tension was observed.

Then the patient is instructed to hyperventilate as much as possible. After about twenty to twenty-five seconds, with the patient still hyperventilating, the second blood sample is taken.

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It is of the utmost importance that the patient makes every effort to hyperventilate as much as possible. Otherwise false values are obtained. The patient's cooperation is as important in the hyperventilation test as when testing the maximal breathing capacity.

In the immediate postoperative period the patients have too much pain to perform a good hyperventilation test. The change in the arterial oxygen and carbon dioxide tension during this postoperative period is usually very small and is not an expression of the true respiratory reserve.

Oxygen and carbon dioxide tensions (pO_2 and pCO_2) in the arterial blood are determined according to the method of Riley, Proemmel, and Franke. Washing the capillary with physiologic saline solution has been abandoned due to the solubility of both the carbon dioxide and the oxygen in it.[3] The cup is sucked out by means of a special suction line in order to have only a few units of blood covering the upper meniscus of the bubble in the capillary. Then sodium hydroxide solution 4.0 per cent is filled in the syringe cup and used for both the washing down of the capillary and the carbon dioxide absorbtion from the bubble at the same time.

To obtain some information about the accuracy of the method 41 experiments were performed in which the blood was equilibrated fifteen to twenty minutes with a known gas mixture passing through a tonometer. The oxygen and carbon dioxide tension in the blood was then determined. The mean difference between the oxygen tension in the blood and in the gas mixture was –1.8 mm. Hg ± 0.77. As this difference is not statistically significant, the method is considered reliable.

The mean difference between the carbon dioxide tension in blood and in the gas mixture was –2.37 mm. Hg ± 0.59. This difference is significant which makes the values of the carbon dioxide tension less reliable.

TABLE I. RESTING ARTERIAL pO_2 AND pCO_2 IN MM. HG AND THE DIFFERENCE BETWEEN VALUES DURING VOLUNTARY HYPERVENTILATION AND REST (MEAN VALUES AND STANDARD DEVIATION)

GROUP	NO. OF CASES	RESTING ARTERIAL pO_2	RESTING ARTERIAL pCO_2	DIFF. pO_2 HYP. VENT.-pO_2 REST	DIFF. pCO_2 HYP. VENT.-pCO_2 REST
1. Normal	21	86.0 ± 1.1	35.0 ± 1.4	+23.0 ± 2.0	-18.6 ± 2.2
2. Unilateral	35	76.8 ± 1.7	39.6 ± 1.0	+ 8.4 ± 1.7	- 4.3 ± 1.3
3. Bilateral	31	75.5 ± 1.9	38.6 ± 1.4	- 0.2 ± 1.5	+ 0.2 ± 1.5
4. Clinically bad	11	70.1 ± 3.6	39.2 ± 2.4	- 2.2 ± 2.5	+ 6.0 ± 1.7

RESULTS

The patients were divided into groups including: (1) normal persons, (2) patients with unilateral pulmonary tuberculosis, (3) patients having bilateral pulmonary tuberculosis, and (4) patients who were clinically very poor risks.

A resection was planned or performed for all individuals in Groups 2 to 4. The results are shown in Table I and Fig. 1.

Group 1.—Normals.

Group 2.—Patients with unilateral pulmonary tuberculosis needing resection have a much lower ability to increase the arterial pO_2 and decrease the arterial pCO_2 than normal individuals.

Group 3.—In patients with bilateral pulmonary tuberculosis who needed resections there was no ability to increase the arterial pO_2 and decrease the arterial pCO_2. There was on the contrary in several instances a decrease in arterial pO_2 and an accumulation of carbon dioxide during the voluntary hyperventilation.

It is evident that Groups 2 and 3 include patients with a wide range of pulmonary reserve.

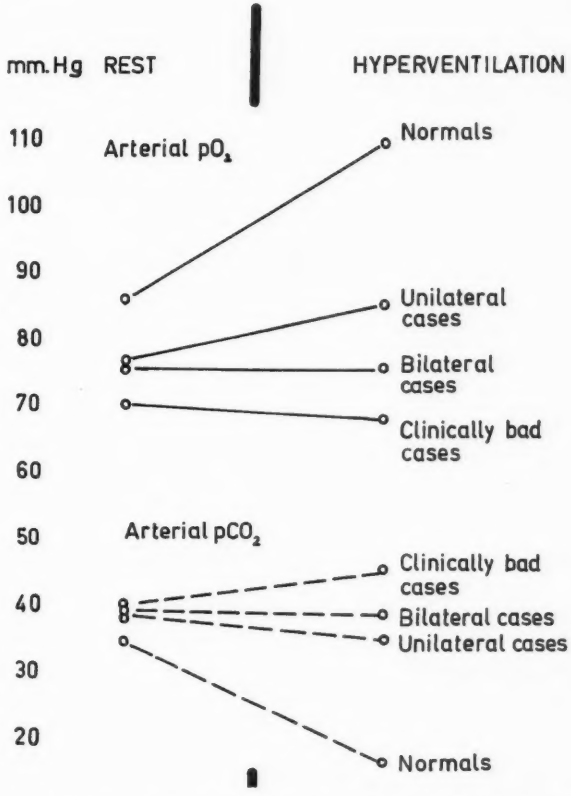

Fig. 1.—Diagram demonstrating the change in arterial pO_2 and pCO_2 during voluntary hyperventilation in cases with a varying degree of respiratory reserve.

If, however, the material is divided according to the amount of tissue removed at operation the groups are too small to show any significant difference between the subdivisions.

Group 4.—A group of clinically very poor risk patients was collected. It included ten patients with far-advanced bilateral tuberculosis and one patient

who had undergone a right pneumonectomy for cancer one year previously. All these patients could walk on a horizontal plane but had to rest after walking only one flight of stairs. The maximal breathing capacity varied between 24 and 68 L.; the average was 46 L. per minute. In this group there was no increase of arterial pO_2 and there was a carbon dioxide accumulation during voluntary hyperventilation. Ten survived the resection. One patient died eight days after an extrapleural pneumonectomy. Autopsy showed cor pulmonale.

Of the ten remaining, seven are respiratory cripples and unable to work. Three patients are working. Of these, one patient is a respiratory cripple but still performs full-time work as a construction engineer. Ten years ago he had a left seven-rib thoracoplasty performed and there is now a big residual cavity in the left upper lobe. Two years ago a right upper lobectomy and a five-rib thoracoplasty was performed. The right lung then had 82 per cent of the total oxygen uptake. After the resection, the patient is only able to walk slowly on a horizontal plane. Maximum breathing capacity is 28 L. per minute. Of the other two working patients, one works six hours a day as a clerk, the other is a full-time laboratory nurse.

A 30-year-old patient with only a functioning left lung had normal values (during hyperventilation an increase in arterial pO_2 from 85 to 109.6 mm. Hg and a decrease in pCO_2 from 35 to 7.4).

A 61-year-old patient with only a remaining left lung was, however, a respiratory cripple. The arterial pO_2 decreased from 55.3 to 54.1 mm. Hg during voluntary hyperventilation, and there was an increase in the arterial pCO_2 from 40.2 to 50.4.

In one patient the left phrenic nerve was damaged during the removal of a mediastinal tumor six years earlier. The left diaphragm now made no excursions. Bronchospirometry showed 34 per cent of the total oxygen uptake and 23 per cent of the ventilation in the left lung. During voluntary hyperventilation the arterial pO_2 did not rise significantly (only from 86.9 to 87.9 mm. Hg), but there was a pronounced decrease of pCO_2 from 33.9 to 20.8 mm. Hg.

DISCUSSION

During a voluntary hyperventilation normal individuals have an ability to increase the arterial pO_2 and decrease the arterial pCO_2. This ability becomes less pronounced in cases where lung parenchyma has been destroyed and ventilation impaired. In some of the patients with far-advanced pulmonary disease an abnormal reaction with a decrease of the arterial pO_2 and an accumulation of carbon dioxide has been observed during the hyperventilation. We believe that it requires more work for these patients to hyperventilate than is required for normal individuals and the corresponding gain in ventilation is insufficient. In persons with tuberculous empyema or a fixed diaphragm after bilateral pneumothoraxes the work required to hyperventilate is considerable but the increased ventilation is negligible. A decreased arterial pO_2 and a carbon dioxide accumulation may then be present.

In this group of cases with little respiratory reserve most patients will survive the operation. They are usually somewhat more crippled after the

operation, but they may have little or no sputum and their general condition may improve.

In this group of patients with little respiratory reserve it is important to check the arterial oxygen and carbon dioxide tension at intervals after the operation. With oxygen therapy the patient may have a good color but a pronounced carbon dioxide retention. A tracheotomy may be performed early to improve the ventilation and bring the patient through the immediate postoperative period. The dead space will diminish with approximately 100 ml. after a tracheotomy and the airway may be kept clear by aspirations until the patient is strong enough to cough effectively.

SUMMARY

The arterial oxygen and carbon dioxide tension at rest and during a voluntary hyperventilation has been investigated in persons with varying degrees of respiratory insufficiency. Patients without ability to increase the arterial pO_2 and decrease the pCO_2 during hyperventilation are considered to have very poor respiratory reserve.

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THE EFFECT OF CAVERNOSTOMY ON GIANT PULMONARY CAVITIES

Report of Twenty-eight Cases

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THE opening and drainage of pulmonary tuberculous cavities is the oldest surgical procedure tried for the cure of pulmonary tuberculosis. Cases where cavernostomy was used have been reported occasionally since the seventeenth century, as Le Carboulec[1] and Elliott[2] have demonstrated. The establishment of this procedure as a treatment for pulmonary tuberculous cavities, however, is due properly to De Cerenville,[3] of Lausanne, who not only combined it with some primitive thoracoplasty, but also practiced the chemotherapeutic tamponade of cavities with gauze soaked in iodoform and other antiseptic agents.

The views of De Cerenville were later confirmed by the work of Sauerbruch,[4] who showed the advantages of a preliminary thoracoplasty in cavernostomy.

The modern work of Coryllos and Ornstein[5] on the importance of draining bronchi in the treatment of cavities gave special interest to cavernostomy; it was possible to interfere directly by draining the bronchus, especially in those cases in which collapse therapy and even thoracoplasty had failed to close the cavity.

Cavernostomy was then established as a supplementary procedure for the treatment of residual cavities after thoracoplasty; the persistence of the cavities was attributed to the nonocclusion of their draining bronchus. The favorable effects of cavernostomy in the treatment of residual cavities encouraged further research, especially after the discovery of the antibiotics. O'Brien[6] and Bernou,[7] and their respective associates and Bonniot and Joly[8] also applied the procedure in instances of giant cavities without any previous thoracoplasty, with hopeful results.

The favorable results of the continuing research induced Maurer of Davos to try to substitute cavernostomy, in many cases, for surgical collapse therapy; he increased the indications for its application, since with his own bloodless procedure, physicians not specializing in surgery then would be able to practice it.

Maurer's[9, 10] technique consists of catheterization of the cavity, widening of the chest wall sinus by means of laminaria, tamponade with gauze soaked in antibiotics, and, finally, closure of the cavity's draining bronchi by means of diathermocoagulation.

As Maurer's published results seemed to be more than satisfactory, naturally we were also interested in the application of the procedure to patients with giant pulmonary cavities, who, for various reasons, could not be subjected to other effective treatment.

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In the application of cavernostomy in our cases, we followed a technique more simple than Maurer's. First we performed the catheterization according to Monaldi's method; then we widened the chest wall sinus by removing and inserting rubber drainage tubes of progressively increasing diameters. In this way we were able to obtain a progressive widening of the sinus without the use of laminaria sticks, which protected the patient from undesirable reactions. The final stage in the procedure was the chemotherapeutic gauze tamponade; if necessary, cauterization of the open draining bronchi was performed.

TABLE I

	NO. OF CASES	CLOSURE OF CAVITY. OBLITERATION OF DRAINING BRONCHUS	SHRINKING OF CAVITY. OPEN DRAINING BRONCHUS	WITHOUT EFFECT	AGGRAVATION
Sex					
Male	9	6	2	–	1
Female	19	4	8	4	3
Total	28	10	10	4	4
Age (in years)					
17-25	10	3	3	2	2
26-35	15	5	7	2	1
36-45	3	2	0	–	1
Total	28	10	10	4	4
Duration of disease before operation					
12 mo.	4	3	0	1	–
12-36 mo.	11	3	5	1	2
More than 3 years	13	4	5	2	2
Total	28	10	10	4	4
Extent of disease before operation					
Moderately advanced	12	7	4	–	1
Far advanced	16	3	6	4	3
Total	28	10	10	4	4
Description of pulmonary disease before operation					
Unilateral with single cavity	11	6	4	–	1
Unilateral with multiple cavities	3	1	1	1	–
Bilateral with single cavity on one side	5	1	–	3	1
Bilateral with multiple unilateral cavities	5	1	4	–	–
Bilateral with bilateral cavities	4	1	1	–	2
Total	28	10	10	4	4

RESULTS

Our total number of cases was twenty-eight. In all cases streptomycin and PAS treatment had been applied previously, before admission to the sanatorium. In all cases an induction of pneumothorax had also been tried unsuccessfully because of pleural adhesions. Application of thoracoplasty or lobectomy was impossible either because of the poor general condition of the patient or because of contralateral involvement. Table I presents the analytic results

of cavernostomy connected with the sex and age of the patient, chronicity, and extent of the disease as well as the anatomic and pathologic alterations.

The roentgenographic disappearance of the cavity alone must not be considered as a complete therapeutic result; the disappearance must be followed by the permanent obstruction of the draining bronchi.

The cases in which shrinking of the cavity was marked but no obstruction of the draining bronchi was obtained were considered only improved. Their treatment must be completed with thoracoplasty if this is possible.

Cases which, during a period of at least six months, did not present any change from the application of cavernostomy were classified as without effect, while the cases in which, after the institution or during the time of cavernostomy, clinical and focal aggravation were noted were reported as aggravated.

The possibility of favorable results seems to be better in men than in women; to explain this phenomenon the neurovegetative inconstancy generally observed in women must be taken into consideration; because of it women tolerate the continued and long-sustained irritation caused by cavernostomy with greater difficulty. It seems that there is no essential difference among the three categories of age mentioned in Table I; however, from the fact that the shrinking of the cavity presupposes a preserved elasticity of the pulmonary tissue, to a sufficient degree, it is understood that, from this point of view, an advanced age brings forth difficulties regarding the favorable influence of the cavernostomy. The difference in the percentage of the favorable effects obtained in the various categories described in Table I and connected with the period of the disease before the institution of cavernostomy must also be attributed to the same reason. The longer the period of disease before the institution of cavernostomy the greater the presupposition of a sclerosis of pulmonary tissue as well as of the wall cavity; this, of course, renders difficult the attainment of the complete shrinking closure of a cavity.

The extent of the disease plays an important part in the effects obtained by cavernostomy. In cases of slowly progressing tuberculosis, the possibility of success in catheterized cavities reached 58 per cent, while in a progressive form of the disease, the percentage hardly amounts to 18 per cent. The greater possibility of success in catheterized cavities, therefore, is found in unilateral tuberculosis with a single cavity, and the possibility decreases progressively in the other categories. In Table II the results of cavernostomy are given analytically; the localization of the cavity, its size, the condition of the pulmonary tissue around the cavity, and finally the duration of the cavernostomy in each case are also included.

The greatest rate of cure is observed in cavities localized in the medium and lower parts of the lung, while in the cavities of the upper part the percentage evidently diminishes. This may be attributed, first, to the lack of sufficient healthy pulmonary tissue around the cavities of the upper region, and second, to the existence of extended adhesions between the cavities and the thoracic wall. The cavities located in the medium and lower regions of the lung are mostly free of adhesions.

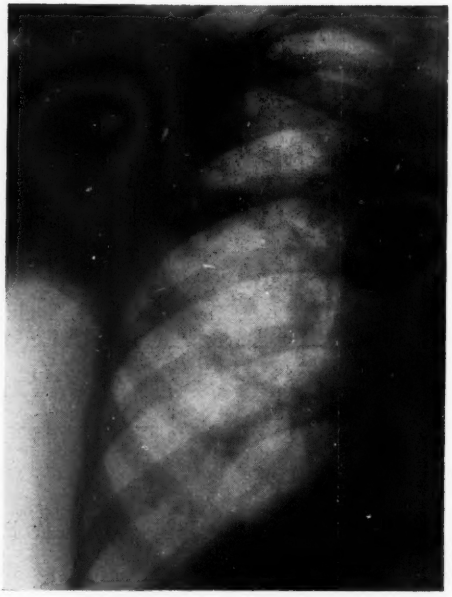
The size of the cavity does not seem to influence the therapeutic effect. The percentage of favorable results is about the same in the two categories of Table II. We must point out, however, that the size of the cavities in our cases is not caused solely by the ravage of pulmonary tissue, but depends considerably upon its tension, caused by the check-valve mechanism function of their draining bronchi.

TABLE II

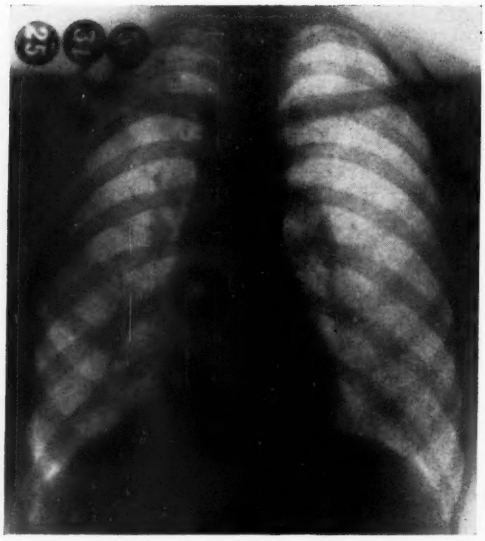
	NO. OF CASES	CLOSURE OF CAVITY. OBLITERATION OF DRAINING BRONCHUS	SHRINKING OF CAVITY. OPEN DRAINING BRONCHUS	WITHOUT EFFECT	AGGRAVATION
Localization of cavity					
Upper region	25	7	10	4	4
Medium region	1	1	–	–	–
Lower region	2	2	–	–	–
Total	28	10	10	4	4
Size of cavity (in cm.)					
4 to 7	21	7	8	3	3
8 to 11	7	3	2	1	1
Total	28	10	10	4	4
Duration of cavernostomy (in months)					
2 to 6	7	3	–	1	3
7 to 12	7	4	1	2	–
12 to 25	14	3	9	1	1
Total	28	10	10	4	4
Around cavity pneumonic tissue					
Healthy	15	8	6	–	1
Changed	13	2	4	4	3
Total	28	10	10	4	4

The condition of the lung tissue surrounding the cavities seems to influence essentially the therapeutic effect, as can be observed in Table II. In those cases in which the cavities were surrounded by a healthy pulmonary tissue, the percentage of cure amounted to 53 per cent; in cases with the tissue affected either by a tuberculous process or sclerosis, the percentage scarcely reached 15 per cent. The duration of the cavernostomy cure in our cases was two to twenty-five months. Within two months aggravation and death occurred in three cases. In the other cases the minimum cure time was six months; cure time which lasted more than twelve months concerns cases in which the occlusion of the draining bronchi became difficult because of extensive alterations and hardening of the walls. There were ten cases in which closing of the cavity and permanent occlusion of the draining bronchi occurred; this was 36 per cent of the total number of cases. The patients in this group left the sanatorium and went back to their work.

The time from the removal of the catheter to the term of the cavernostomy in those who recovered was for three cases, two years; for two cases, one year and six months; for three, one year; and for two cases, six months. In all these

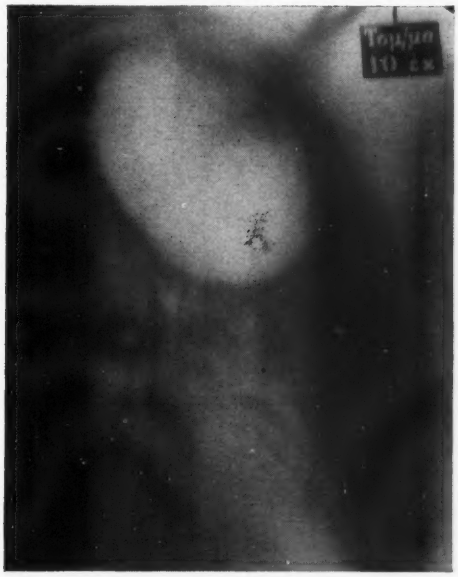


A.



B.

Fig. 1.—*A*, Giant cavity covering the upper third of right lung. *B*, Twenty-five months after the removal of the catheter. No evidence of cavity.



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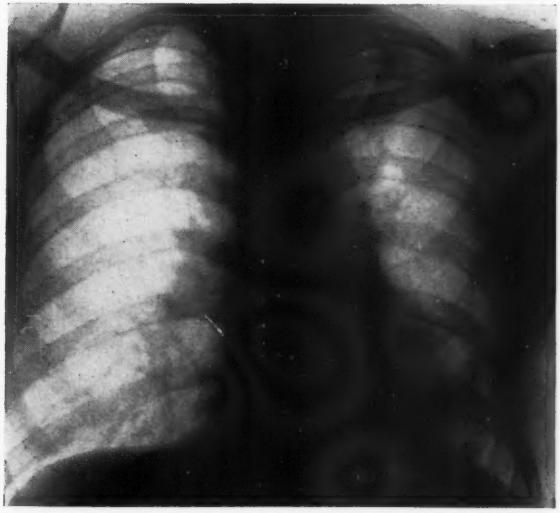
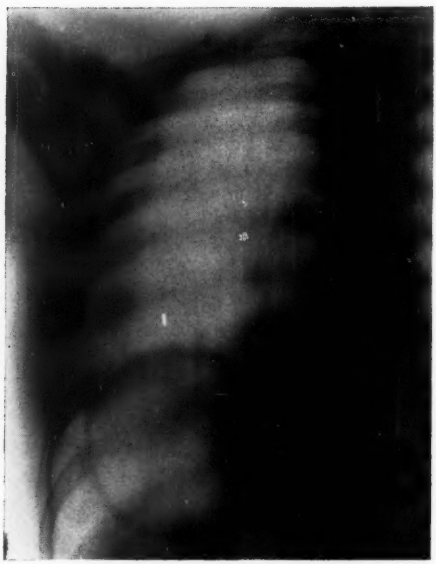
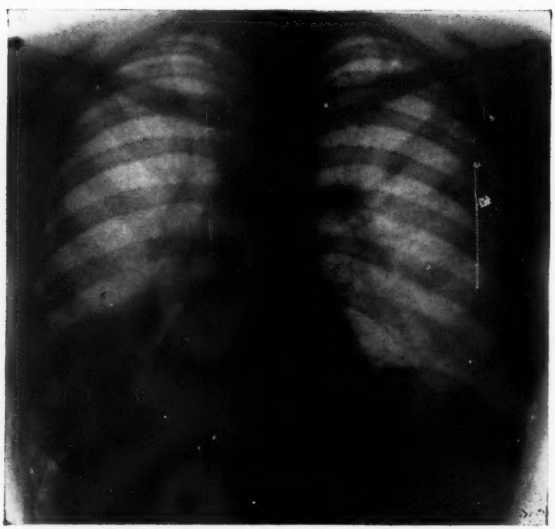


B.

Fig. 2.—*A*, Giant cavity in the upper left lobe. *B*, Nineteen months after the removal of the catheter. No evidence of cavity.



A.



B.

Fig. 3.—*A*, Giant cavity covering lower third of right lung. *B*, Twelve months after the removal of the catheter. No evidence of cavity.

cases the expectoration was continuously negative for tubercle bacilli and the consequent roentgenologic control showed stability of the favorable result obtained.

The cases with shrinking of the cavity but with nonocclusion of the draining bronchi amounted to ten, that is, approximately 36 per cent.

In two of the previously mentioned cases, supplementary thoracoplasty was applied and in one a successful lobectomy; in the remaining seven cases, at present any supplementary intervention is impossible.

The cases without effect and those aggravated amount to 28 per cent of the total; in all these unsuccessful cases the patient died in two to eighteen months from the institution of the cavernostomy, some of them because of the nonarrest of the progression of the tuberculous process and others because of the aggravation caused by the intervention.

SUMMARY

The results of twenty-eight cases with giant cavities to which cavernostomy was applied following Maurer's technique are presented: complete and permanent cavity closure and occlusion of the draining bronchi, 36 per cent; shrinking of the cavity without occlusion of the draining bronchi, 36 per cent; no shrinking whatever or aggravation, 28 per cent.

The contribution of the various factors connected with the constitution, clinical evolution, pathologic and anatomic form and localization of alterations, as regards the favorable or unfavorable effects of the cavernostomy is shown in the two tables.

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EXPERIMENTAL RECONSTRUCTIVE SURGERY OF THE TRACHEA

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WITH the advancement of modern surgical techniques, anesthesia, and pre- and postoperative management, surgical reconstruction of the air passages is of more importance now, especially since there are a great number of pathologic processes in which it can be applied, such as benign and malignant tumors, stenosis, traumas, fistulas, and extrinsic and intrinsic compressions.

The experimental work carried out in animals has also been a decisive influence on the advancement of surgical techniques, so that at the present time it is possible to predict the outcome of repairing either the trachea or bronchi, anastomosing the air passages, and reconstructing previously created defects, with the use of plastic material and grafts.

Ferrari and Gardenghi,[1] in 1948, reported the successful resuture of the trachea after resecting a benign fibroadenohemangioma. Belsey,[2] in two cases of malignant tumors of the trachea, used a stainless steel wire mesh surrounded by a free graft of fascia to repair the defect created after resecting the tumor. In 1951 Mathey[3] reported the case of a tumor at the bifurcation of the trachea in which he performed a wide resection and reconstruction using a stainless steel wire for the sutures, without producing stenosis. Evans[4] repaired a large defect originated by the resection of a benign tumor of the trachea with a stainless steel wire mesh covered with a skin graft.

Cotton and Penido[5] reported the successful resection of almost all of the trachea in two patients with carcinoma, after which reconstruction was possible by means of a stainless steel tube. Cahan[6] reported the case of a carcinoma of the lower third of the trachea in which excision was followed by repair with a tantalum gauze fascia lata graft; sixteen months afterward the patient was living and had no complaints. Metrás and associates[7] performed a bronchotomy followed by anastomosis, in a case of adenoma. Kergin,[8] after resecting a carcinoma of the intrathoracic trachea, covered the defect with a portion of pericardium; later on, due to extension of the tumor, he performed a right pneumonectomy using a portion of the right bronchus to cover the defect. Goldman,[9] in 1952, reported five cases of transpleural bronchotomy. Gebauer,[10, 11] in 1950, reported the use of a stainless steel wire mesh covered with a dermal graft in repairing the defect produced by resecting a portion of the wall of the main bronchi, in cases of tuberculous bronchostenosis and also in repairing the trachea in cases of stenosis. Paulson[12] reported having used skin grafts to repair large defects in the trachea and bronchi, also in cases of tuberculous stenosis. Mathey,[13] using Gebauer's technique, was successful in repairing one of the main bronchi, also in a case of tuberculous

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bronchostenosis. Harrison,[14] in 1936, reported the repair of the traumatic type of stenosis of the trachea by skin grafting. Griffiths[15] performed an end-to-end anastomosis after resecting a fractured cartilage in one of the main bronchi. Belcher[16] reports an accidental section and successful resuture of a bronchus, using a fragment of intercostal muscle to cover the repair; bronchoscopy later on showed a slight degree of stenosis. Mathey and Oustriers[17] performed an end-to-end bronchial anastomosis, covered with a skin graft after an accidental division of the main stem bronchus. Scanell[18] reported the case of a ruptured bronchus following a closed injury to the chest, treated by immediate thoracotomy and repair. Levit[19] in 1912 reported the use of a free graft of fascia lata in repairing old fistulas in the air passages. Neuhof[20] reported the successful closure of old tracheotomies also using free grafts of fascia lata. Brea,[21] like many others, has reported successful resuture after removing foreign bodies from the bronchi. Sloan and Cowley[22] reported a case of a posterior mediastinal tracheotomy in a case of extrinsic compression due to an aortic aneurysm.

MATERIAL AND METHODS

For this study, we used a dog in our experiments.

The dog is placed on the operating table with the neck extended and under surgical anesthesia with pentobarbital. To expose the trachea, an incision is made over the anterior portion of the neck at the midline, from the thyroid cartilage to the base of the neck. The trachea is next dissected cleanly down in approximately 10 cm., after which the surgical procedure of choice, in each of the groups which will be described, is carried out. The neck is then closed by intermittent silk sutures.

Altogether we used fifty dogs grouped as follows:

1. Section and end-to-end anastomosis.
2. Homotopic autografts.
3. Homotopic homografts.
4. Heterotopic autografts.
5. Platelike heterotopic grafts.

Section and End-to-end Anastomosis (Fifteen Cases).—In five of the cases an end-to-end anastomosis with intermittent silk sutures was performed, and in one case the anastomosis was performed with sutures in U.

In two cases a portion of the trachea was excised and an end-to-end anastomosis with silk sutures in U was performed. In seven similar cases we used stainless steel wire for the sutures, and in the last case the section was done diagonally using stainless steel wire for the sutures.

All of the dogs in this group died between three and six weeks after the operation.

Homotopic Autographs (Twelve Cases).—A portion of the trachea was excised and after a few minutes resutured with silk sutures in U in four cases and with stainless steel wire sutures in U in three cases. There was marked stenosis in the first group, in which the dogs died five to seven weeks after the operation, and in two cases in which stainless steel wire was used for the

sutures. In three cases, excision was made of a portion of the trachea, leaving the posterior intercartilaginous membrane in situ, replacing the excised portion after a few minutes with three stainless steel wire sutures in U. All the dogs in this group were sacrificed six weeks after the operation. In two cases, the posterior intercartilaginous ligament was sectioned, leaving the trachea untouched. The dogs were sacrificed six weeks afterward.

Homotopic Homografts (Fifteen Cases).—In this group we used homotopic homografts, either fresh, performing two operations simultaneously, or using material kept in different types of media. In two cases the graft had been kept in alcohol, the end-to-end anastomosis was done with intermittent silk sutures, and the animals died thirty and forty days after the operation. In five cases the grafting was done simultaneously, from one dog to the other, using two stainless steel wire sutures and three intermittent silk sutures. All of the animals in this group died between the first and the seventh day after the operation. In four cases, the graft was kept in normal saline solution with penicillin and streptomycin; again in this group all of the animals died between five and thirty days after the operation. In three cases we used a lyophilized graft rehydrated by placing it in normal saline solution; the anastomosis was performed with two stainless steel wire sutures in U and several intermittent silk sutures; the animals in this group died between ten and forty-two days afterward.

Heterotopic Autografts (Four Cases).—In this group the graft was prepared by removing a portion of the cartilaginous part of the ear of the same animal which was placed around the previously resected portion of the trachea with three stainless steel wire sutures in U, reinforcing the suture line with several intermittent silk sutures. The animals in this group died from two to three days after the operation.

Platelike Heterotopic Grafts (Four Cases).—A small window (1 cm. in size) was made in the anterior portion of the trachea, after which a fragment of the cartilaginous portion of the ear of the dog, slightly larger than the window, was sutured using intermittent silk sutures over the previously created defect. The animals in this group were sacrificed 15, 20, 35, and 50 days, respectively, after the operation.

RESULTS

In all the cases, a macroscopic and microscopic study was made immediately after the animal died or was sacrificed, with particular emphasis on the state of the suture line, degree of epithelization, and the state of the tracheal cartilages both from the grafts and the receptor. The results of these studies can be summarized as follows:

1. Section and end-to-end anastomosis: In all those cases in which silk was used for the sutures, there was stenosis to complete obstruction (Fig. 1). The microscopic study revealed loss of the mucous membrane at the suture line with infiltration by lymphocytes, polymorphonuclears and plasma cells, evidence of an intense inflammatory type of reaction.

In all those cases in which stainless steel wire was used for the sutures, there was no stenosis (Fig. 2); with the exception of one case, there were no evidences of inflammatory reaction or destruction of the material used for the sutures; the microscopic study revealed formation of new mucosa at the level of the suture line, the scar tissue being formed with fibrous tissue and an occasional residual inflammatory type of cell.

Fig. 1.

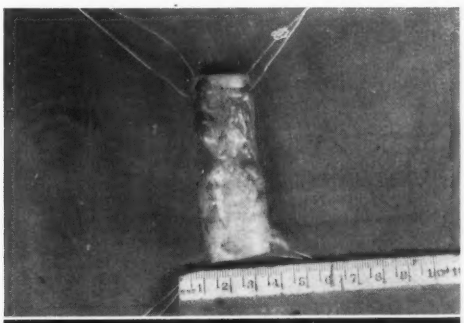

Fig. 2.

Fig. 1.—Stenosis in a case of end-to-end anastomosis with silk sutures.

Fig. 2.—End-to-end anastomosis with stainless steel wire sutures; the trachea has been exposed longitudinally. Notice absence of stenosis.

2. Homotopic autografts: In all the cases in which silk was used for the sutures, there was a severe degree of stenosis (Fig. 3), with an inflammatory

Fig. 3.

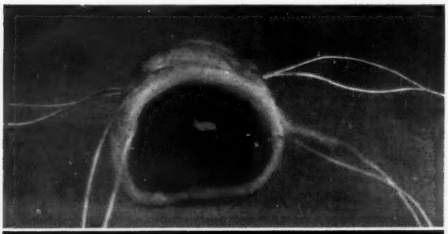

Fig. 4.

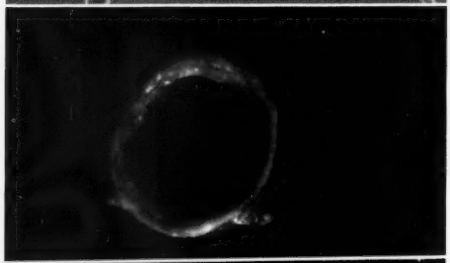

Fig. 5.

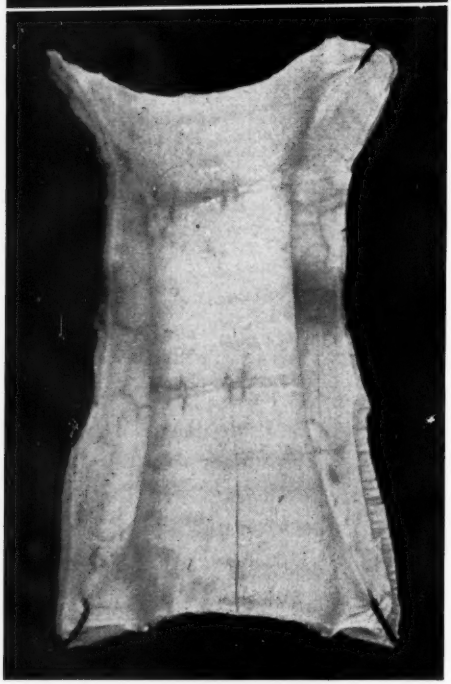

Fig. 3.—Homograft showing a complete stenosis.
Fig. 4.—Autograft with stainless steel wire sutures. Notice absence of stenosis.
Fig. 5.—Autograft with stainless steel wire sutures. Notice both suture lines.

type of reaction around the trachea and in some cases pus formation; microscopically there was necrosis at the site of the graft and a great amount of granulation tissue. There was also complete loss of the mucosa and destruction of the cartilaginous tissue. In one of the cases in which stainless steel wire was used for the sutures, there were no major macroscopic abnormalities (Figs. 4 and 5). The microscopic study showed the presence of scar tissue at the suture line, complete epithelization at the inner surface, absence of inflammatory reaction, and partial ossification of the tracheal cartilage. In the remaining two cases there was a severe degree of stenosis, in an hourglass fashion with superimposed infection; the microscopic study showed that the graft had been replaced by fibrous tissue with no evidences of new cartilage formation. There was also loss of the mucosa and, in one of the cases, squamous metaplasia.

When the trachea had been excised leaving the posterior longitudinal ligament untouched, there was no stenosis and microscopically there was formation of new mucosa, presence of fibrous tissue, and mucous glands. Similar results were obtained in the two cases in which the posterior longitudinal ligament had been excised leaving the trachea untouched.

Fig. 6.—Fresh homograft showing complete destruction.

3. Homotopic homografts: In two of the cases in which silk was used to suture tracheal grafts preserved in alcohol, the necropsy specimens revealed a severe degree of stenosis and microscopically complete replacement of the graft by fibrous tissue, with loss of the tracheal structure and an intensive inflammatory type of reaction. In three of the cases in which a fresh graft was used, there was a severe degree of stenosis and in three cases complete

destruction of the graft (Fig. 6); microscopically there was replacement of the graft by fibrous tissue showing a great number of lymphocytes, polymorphonuclear leukocytes, loss of epithelial tissue, and destruction of cartilaginous tissue. In four cases in which the graft had been preserved in normal saline solution (with penicillin and streptomycin), there was stenosis in three and destruction in one. The microscopic study showed loss of the normal structure of the trachea with a few degenerated cartilages, foreign body reaction, pus formation, and squamous metaplasia of the mucosa. In the three cases in which a lyophilized graft had been used, there was a severe degree of stenosis with fibrous and inflammatory type of tissues.

4. Heterotopic autografts (Fig. 7): the macroscopic specimens in three of the cases showed a complete destruction of the graft with superimposed infection (Figs. 8 and 9). The microscopic study showed a great number of leukocytes, predominantly lymphocytes at both ends of the suture lines, together with some areas of necrosis; the other dog, which died one day after the operation, showed the graft to be collapsed, and although the histologic picture seemed to be normal, there was a great number of dilated vessels and necrotic foci.

5. Platelike Heterotopic Grafts: There was no stenosis in any of the specimens obtained at necropsy (Fig. 10); there was a number of firm adhesions between the site of the graft and the peritracheal tissues and microscopic degeneration of the cartilaginous platelike graft which was covered with fibrous and inflammatory tissue which was found to be less, the more the time between the operation and the study. The inner surface of the trachea was found to be also more epithelized in those cases which were sacrificed later on in the course of these studies.

DISCUSSION

The results obtained in the first group show that the silk sutures were not sufficiently strong to maintain both ends of the anastomosed tracheal cartilages together, thus the retractile power of the trachea and the superimposed infection, since it is a septic air passage, induced the destruction of the suture line at the time new granulation tissue had been formed, which in turn brought about the stenosis in an hourglass fashion. Therefore, to keep both ends of the anastomosis together, stainless steel wire was used for the sutures with good results, even in those cases in which a portion of the trachea had been excised.

The stenotic process was also found in those cases in which a homotopic autoplastic grafting was done. While those cases in which silk was used for the sutures showed a severe degree of stenosis comparable with the former group, in those cases in which stainless steel wire was used, besides the stenotic process, there was superimposed infection, with the exception of one case. This led us to think not only that it is necessary to keep both ends of the anastomosis together, but also that both the nutritional and infectious factors played an important role in our failures, since when the posterior longitudinal

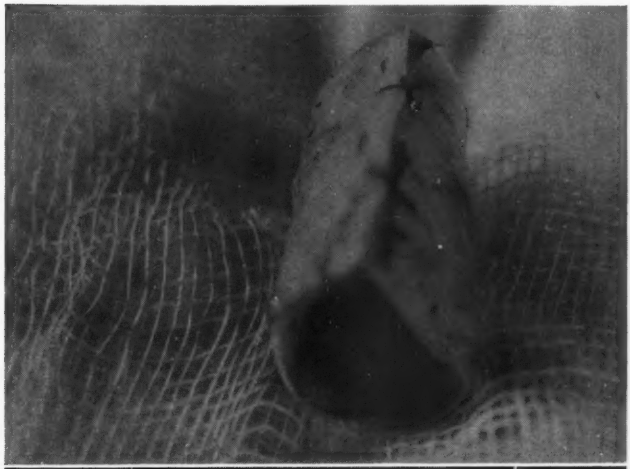

Fig. 7.

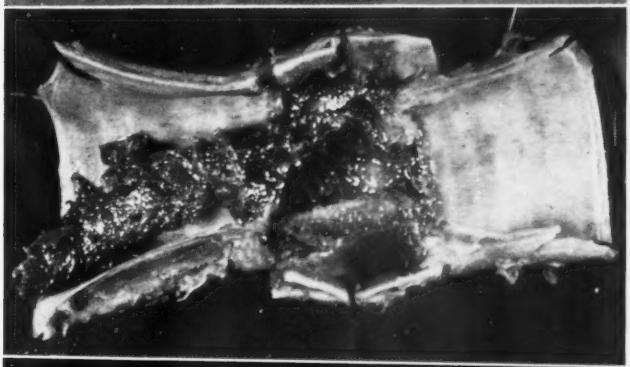

Fig. 8.

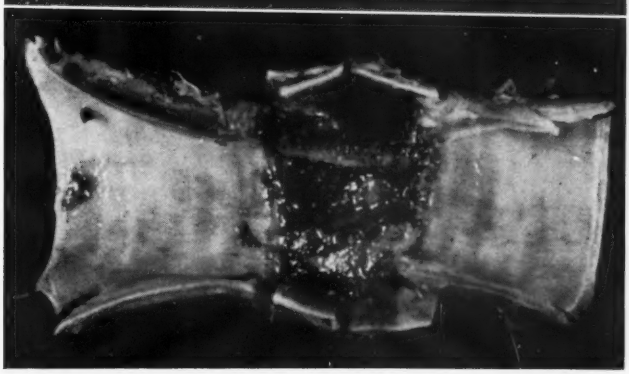

Fig. 9.

Fig. 7.—Graft taken from the cartilaginous portion of the ear ready to be transplanted.

Fig. 8.—Graft taken from the cartilaginous portion of the ear. Notice a blood clot obstructing the lumen of the trachea.

Fig. 9.—Same case after removing the clot. Notice the beginning of the necrotic process.

ligament was left untouched, the cases responded very well; we feel that the infectious factor is more important in producing the stenotic process.

The results obtained in Group 3 show that, in some cases, besides the stenotic process, there is absorption and even complete destruction of the graft, both these reactions being a manifestation of incompatibility between graft and receptor. The only tissues which are not destroyed in grafting from one animal to another of the same kind are: cornea, cartilage, bone, and blood vessels. In this particular case, we feel that it was either a biologic type of reaction (antibody-antigen) or a special type of cellular individuallity which brought about the failure in our homograft cases.

In the four cases in which the graft was taken from the cartilaginous portion of the ear of the same animal (Group 5), there was also a stenotic process; this, however, was originated by a complete collapse of the graft which caused retention of secretions and clots and a concomitant superimposed infection.

In the last group, both the homograft and the autograft were successful. This may have been because the defect produced in the trachea was small and the graft acted only as a scaffold or, as has already been demonstrated, the cartilaginous tissue was well tolerated by the receptor.

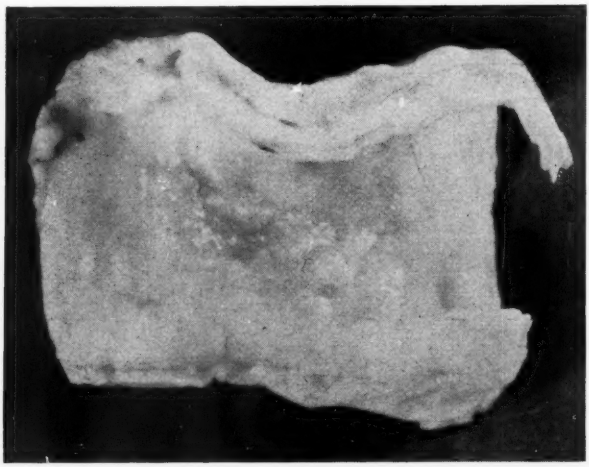

Fig. 10.—Inner surface of the trachea showing a platelike heterotopic graft in a homotropic autograft case.

CONCLUSIONS

1. The end-to-end anastomosis of the trachea must be carried out using a nonabsorbable material for the sutures (such as stainless steel wire) in order to hold both ends of the anastomosis together.

2. Since the air passages constitute a natural septic site, the infectious factor must always be taken into consideration when surgery is performed either in the trachea or bronchi.

Fig. 11.

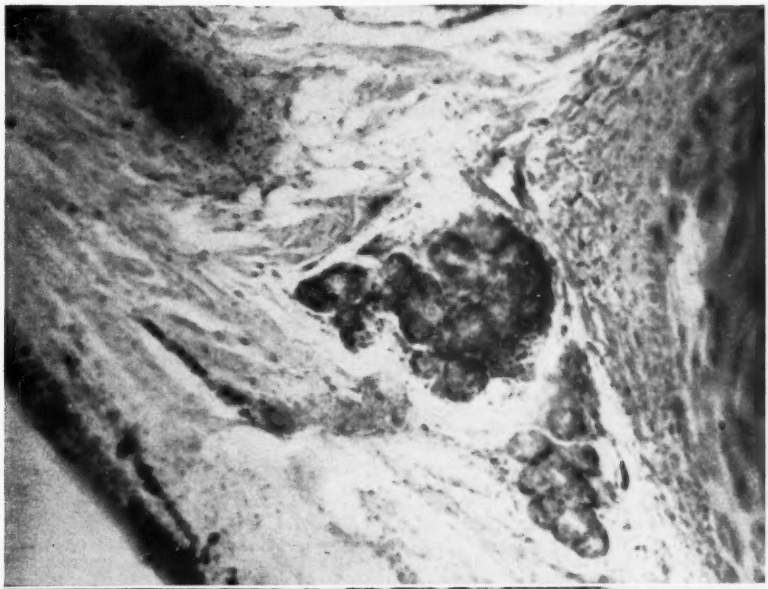

Fig. 12.

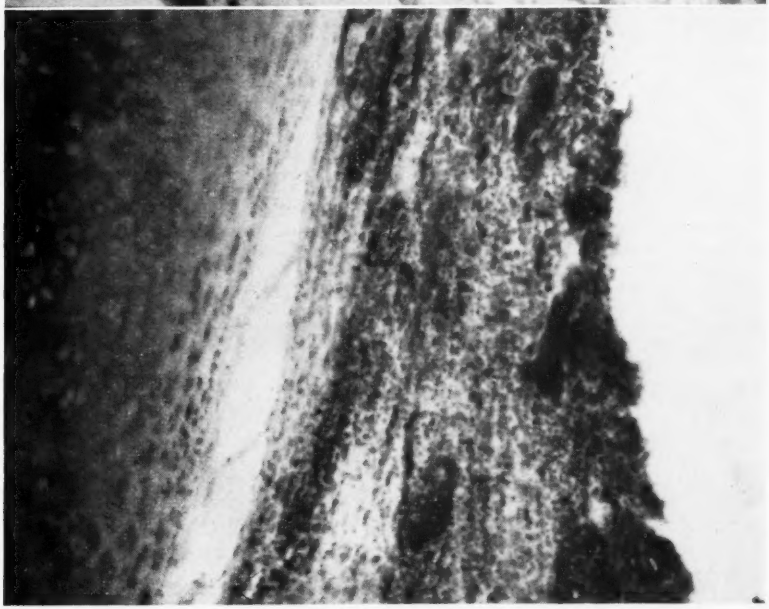

Fig. 11.—Photomicrograph showing scar tissue formation, new cartilage, and a number of inflammatory cells and epithelium covering the inner surface of the scar tissue.

Fig. 12.—There is complete loss of the epithelium and presence of an inflammatory tissue in a platelike heterotopic graft.

3. In the light of present knowledge, the use of either fresh or preserved homotopic homografts is not to be advised.

4. It is possible to use either heterotopic autografts or homografts in repairing small defects in the trachea.

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MEDIASTINAL GRANULOMAS

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MEDIASTINAL granulomas have been of increasing clinical significance since the principle of surgical exploration for indeterminate mediastinal lesions has become well established.[1-3] The majority of granulomas are cystic lesions arising from lymph nodes, usually in the paratracheal region. Most of them occur as an end result of chronic granulomatous inflammation; others present a more acute granulomatous histologic reaction. In the past, the etiological basis has been assumed to be tuberculosis, and the lesions have been designated "mediastinal tuberculomas." Actually the cause of most of these lesions cannot be determined accurately at the present time, and we believe that they should be designated "mediastinal granulomas."

It was Grace, in 1942,[4] who reported the first excision of a mediastinal granuloma with an excellent result. Two years later, Blades and Dugan[5] described another surgical case, that of a 56-year-old Army officer, and in 1948, Tjamouranis[6] contributed the third. Samson and co-workers in 1950[7] added two cases of Paulson's to these plus four new cases of their own. That same year Peräsalo[8] in Finland reported his case, making a total of ten cases. In the discussion of the paper by Samson and co-workers, Woodruff and Goldman spoke of similar cases, but these should not be included because of insufficient data. In 1951, Storey and Lyons[9] described six more mediastinal granulomas, five of which were surgical. At about the same time Rapant and Dvoracek[10] described their case. This makes a total of sixteen mediastinal granulomas proved at thoracotomy. To our knowledge there have been no more recent reports. We wish to add sixteen cases in which operation was performed in the recent past at the Mayo Clinic, and to emphasize that mediastinal granuloma represents a much more common problem than the paucity of literature would indicate.

AGE AND SEX

Mediastinal granulomas are commonly found in young adults, the average age in our series being 32 years. Eleven of the sixteen patients were between 19 and 39 years, while the oldest was 59 and the youngest 2. Neither sex was favored, as eight males and eight females constituted the group.

SYMPTOMS

In general, it is fair to state that mediastinal granulomas cause few or no symptoms. Ten of our patients had no complaints referable to the chest while three had minimal symptoms. In all thirteen of these, the lesions were picked

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up on routinely made roentgenograms of the chest; namely, those made in general surveys, those made in Army or Navy preinduction examinations, or those made as part of a general physical checkup.

Of the other three patients, one was a 19-year-old college girl who had had four attacks of pleuritic pain associated with fever and a 6-pound loss of weight in the year prior to her clinic visit. The second was a 39-year-old housewife who had had low-grade fever for four months in addition to substernal heaviness and mild exertional dyspnea for two months. The third was a 2-year-old child who had had wheezing, cough, and fever for two and one-half months.

LABORATORY DATA

The routine blood counts were within normal limits—the concentration of hemoglobin varied from 11.6 to 15 grams per 100 c.c. of blood, while the leukocyte counts were all less than 10,000 cells per cubic millimeter except for two patients who had counts of 11,200 and 12,400, respectively. The erythrocyte sedimentation rates also fell within normal range for all except one patient, mentioned previously, who had run a low-grade fever; her sedimentation rate was 48 mm. in one hour (Westergren). Differential counts and the results of urinalysis were not remarkable in any case.

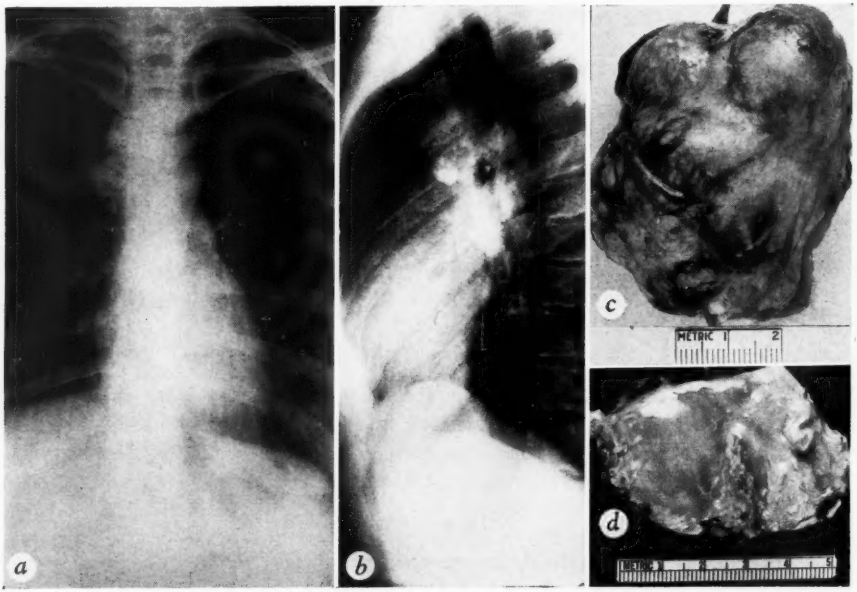

Fig. 1.—*a* and *b*, Roentgenographic appearance of a lobulated mediastinal granuloma in the right paratracheal region of a 32-year-old woman. *c*, Gross specimen. *d*, Cut section of the specimen showing a semiloculated lesion filled with cheesy material.

RADIOLOGIC APPEARANCE AND DIFFERENTIAL DIAGNOSIS

The most common radiographic feature in our series, as in those of others, was the paratracheal location of the lesions with presentation into the right side

of the thorax (Figs. 1, *a* and *b*, 3, *a* and *b*, and 4,*a*). In thirteen of our cases, the lesion was in such a location, while in the fourteenth it projected from both sides of the trachea. In the fifteenth case the tumor appeared as a poorly defined, somewhat irregular mass in the left hilus, and in the remaining case the mass was in the left posteroinferior part of the mediastinum, pulling the esophagus to the left and pushing it anteriorly (Fig. 6, *a* and *b*).

In general, the mediastinal granulomas were well circumscribed with an oval or a smoothly lobulated outline. Often, partial calcification in the periphery was noted (Fig. 6, *a* and *b*), as the majority were cystic lesions with thin, fibrous walls. In addition, some of them presented a central calcific stippled effect, which, when associated with the other features, rendered the roentgenologic appearance very suggestive, if not pathognomonic. It is certainly true that the preoperative diagnosis was correctly made more often in the past five years than prior to that time.

Other lesions to be considered in the differential diagnosis include thymoma, dermoid cyst, enterogenous cyst, thyroid adenoma, lymphoma, neurogenic tumor, aneurysm, and other conditions of rarer occurrence.

PATHOLOGY

Grossly, eleven of the tumors were cystic lesions varying in size from that of a walnut to that of an orange (Figs 1, *c* and *d*, 3, *c* and *d*, 4, *b* and 6, *inset*). The walls were usually hard but easily punctured, being composed of fibrous tissue 1 to 4 mm. in diameter. Gross calcification was often a prominent feature. At operation these cystic granulomas were found to be yellow or white, and all contained a soft, necrotic central mass which closely resembled wet, crushed chalk or cottage cheese. Three of the specimens were solid with much cystic degeneration. The remaining two had the gross appearance of granulomatous lymph nodes with caseation.

Microscopically, the variation observed was consistent with the gross qualities of the lesions. The solid specimens were active granulomas that contained many small tubercles composed of palisaded epithelioid cells, central caseous material, and frequently observed peripheral foreign-body cells and Langhans' type of giant cells. In the solid-cystic variety of tumor, there were more fibrosis and fewer active tubercles. The frankly cystic type seldom had areas with recognizable histiocystic palisading or giant cells, but had acidophilic walls composed of fibrocytes or simply hyaline fibrous tissue (Figs. 2 and 5). Lymphocytes and plasma cells were found in some areas, but their presence was not a prominent feature. Calcification lining portions of the walls was quite common. The central mass was completely amorphous and infrequently preserved in the sections.

BACTERIOLOGY

From thirteen of our specimens, material was injected into guinea pigs and cultured for tubercle bacilli, all giving negative results. Smears from twelve specimens were studied for acid-fast bacilli, with negative results. Ten specimens were subjected to culture for Brucella and eleven for fungi, all of

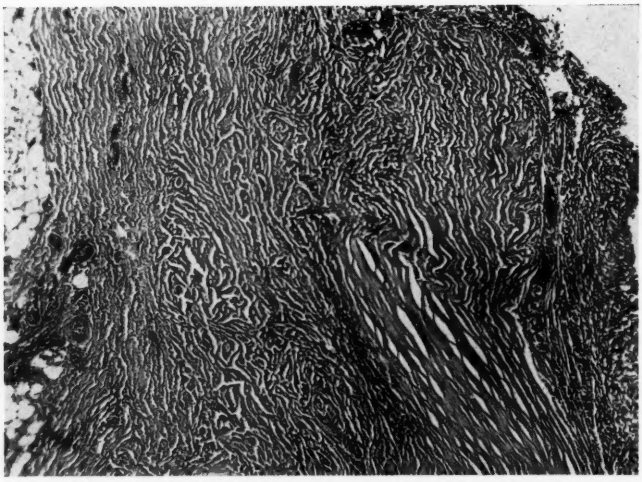

Fig. 2.—Same case as in Fig. 1. Fibrous cyst wall containing lymphocytes, plasma cells, and several Langhans' giant cells. On the right there is an inner rim of palisaded epithelioid cells (hematoxylin and eosin; ×50).

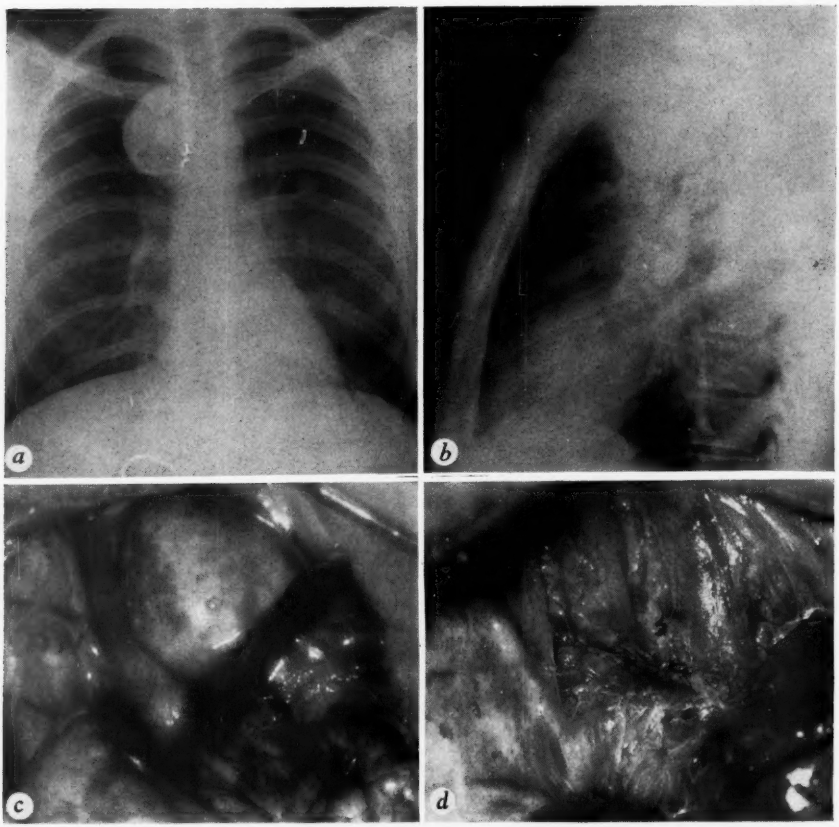

Fig. 3.—*a* and *b*, Asymptomatic, typical, cystic granuloma occurring in the superior mediastinum of a 30-year-old man. *c*, At operation the tumor lay above the azygos vein and behind the superior vena cava, and it was attached to the right lateral wall of the trachea. *d*, After complete excision of the tumor, the bed is well exposed, and the azygos vein has been preserved.

which showed no growth. In two of the cases in which no cultural studies of the specimen were made, cultures or guinea pig inoculation of other material, namely, bronchial secretions and pleural fluid, respectively, gave negative results. Tuberculin tests with old tuberculin or purified protein derivative

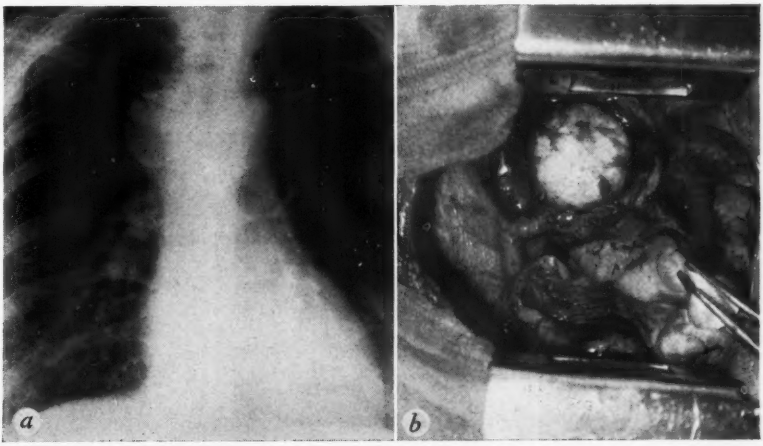

Fig. 4.—*a*, Typical cystic lesion projecting into the right side of the thorax. *b*, View at operation showing the granuloma so adherent to the azygos vein that the vessel had to be sacrificed.

Fig. 5.—Same case as in Fig. 4. Fibrous cyst wall infiltrated with inflammatory cells and having a lining of epitheliold cells.

(P.P.D.) were recorded in eight cases. Four patients were negative to first-strength old tuberculin or P.P.D., two were negative to second-strength P.P.D., one was positive to second-strength P.P.D., and one, the 2-year-old girl, was positive to first-strength P.P.D.

Thus, there were no laboratory clues as to the etiological basis for the granuloma in any case, although we felt justified in making a presumptive diagnosis of primary tuberculosis in the child even though cultures of her bronchial secretions, the only cultures obtained, were negative for tubercle bacilli. Several skin tests for other organisms such as Histoplasma, Blastomyces, and Coccidioides were performed on three patients without significant results.

SURGICAL CONSIDERATIONS

Because of their location and adherence to adjacent structures, the majority of mediastinal granulomas present difficult technical problems to the surgeon.

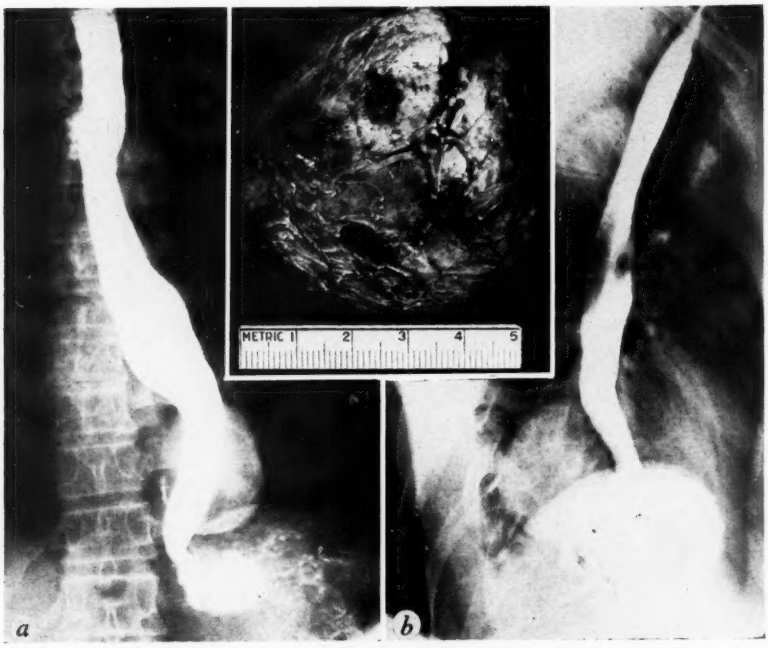

Fig. 6.—*a* and *b*, Barium studies showing the left lateral and forward esophageal displacement by a large, asymptomatic, cystic granuloma occurring in a 52-year-old man. Calcification in the wall of the cyst is well demonstrated. *Inset*, Gross specimen showing the huge, round, cystic nature of the tumor.

They are usually quite adherent to the right lateral wall of the trachea (Fig. 3, *c* and *d*) and may extend down onto the right main bronchus. They lie posterior to the superior vena cava and either above, below, or behind the azygos vein. It is usually difficult to establish a line of cleavage between such a lesion, the trachea, and the superior vena cava. In most cases it is necessary to sacrifice the azygos vein (Fig. 4, *b*). Occasionally, the right upper lobe is adherent to the lesion but can be separated without difficulty. Some cysts are so firmly attached to the aorta or pulmonary artery that enucleation of the

entire lesion is impossible. In such a case it is recommended that the free wall be widely excised, the contents carefully evacuated, and the lining capsule curetted.

Most granulomas, being cystic, have a characteristic white or more often yellow appearance and, when located in the right paratracheal position, present a typical picture.

In our series, one death occurred as a result of technical difficulties encountered when the superior vena cava was injured and could not be repaired. In another case the patient suffered ventricular fibrillation but was revived promptly by cardiac massage. Fifteen of the sixteen patients made excellent recoveries following operation.

COMMENT

There are several controversial features of this subject. Among them is the term "tuberculoma," which previous authors have been wont to apply. We feel that this implies an etiological relationship to the tubercle bacillus. Our studies discourage any certainty on this point. Even in those cases in which acid-fast bacilli were reported by others, the organisms were not identified specifically. It is a well-known fact that acid-fast saprophytes are morphologically indistinguishable from *Mycobacterium tuberculosis*.[11, 12] In the majority of our cases, adequate studies were made according to strict bacteriologic standards.[13-16] Since a specific etiological agent cannot be indicted on the evidence at hand, we feel that the nonspecific term "mediastinal granuloma" is preferable.

Of considerably more importance is the problem of indications for surgical treatment, and closely related to that is the problem of indications for resection or excision at the time of operation. Both of these questions could be answered definitively if the natural course of the tumor were known. Unfortunately, at the present time, prognosis in these cases is in the realm of frank speculation. However, it seems logical to suppose that in the majority of cases the lesion proceeds to benign resolution by continued fibrosis or calcification or both without embarrassment of contiguous vital anatomic structures. This assumption is based on our belief that mediastinal granulomas are relatively common yet practically always asymptomatic.

On the other hand, we have wondered what happens when spontaneous rupture of these cysts takes place. This must occur occasionally in response to indirect trauma or other causes. Are the cystic contents irritating enough to be a cause of idiopathic constricting mediastinitis? Could enough fibrosis occur in the unruptured yet strategically situated large cyst to cause superior vena caval obstruction? We would like to defend such philosophic reverie with the following admittedly inconclusive but provocative arguments.

To begin with, at the time of operation in several of these cases, the granuloma has appeared to be on the verge of spontaneous rupture. Second, in at least three of our cases there were reports of progressive enlargement on serial preoperative roentgenograms. And finally, two cases of mediastinal fibrosis with consequent serious symptoms have come to our attention; presumably the origin was granulomatous.

The first case was that of a 27-year-old woman who came to the clinic on April 19, 1939. For fourteen months she had had an intermittent but increasing cough with recent wheezing and inspiratory whistling. In addition she had coughed up some hard, round pearls (lung stones) on several occasions. Bronchoscopy revealed stenosis involving the right main bronchus at the bifurcation of the upper lobe. Repeated biopsy disclosed only inflammatory tissue. The tuberculin skin reaction had been reported elsewhere as positive. It was felt that she was suffering from enlarged, possibly tuberculous, paratracheal lymph nodes extrinsically compressing the bronchus. From 1939 through 1941, she received six separate short courses of x-ray treatment with a marked amelioration of symptoms. Bronchoscopy performed Jan. 30, 1941, still showed narrowing of the bronchus but to a lesser degree.

Except for mild exertional dyspnea, the patient remained symptomatically well until September, 1949, when a constant dry cough with severe nocturnal paroxysms, a marked increase in exertional dyspnea, and an audible wheeze developed. Physical signs in November, 1949, were compatible with a right bronchial obstruction. Roentgenograms showed a mass anterior to the trachea with central calcification and constriction of both main bronchi, especially on the right. X-ray therapy was undertaken again, but the symptoms became worse. Bronchoscopy on Jan. 17, 1950, showed the lumen of the right main bronchus to be one-fifth of its normal diameter, while that of the left was reduced to one-third.

Exploratory thoracotomy was undertaken on Jan. 24, 1950, through a posterolateral incision over a long segment of the sixth rib. There was a dense stony-hard lesion that involved the lower end of the trachea and both bronchi, and extended into the region of the right pulmonary artery, the superior vena cava, and the pericardium. The mass was so hard that it was impossible to see or feel the trachea or either bronchus. A lymph node taken for biopsy was reported as calcified and inflammatory. Biopsy of the mass showed only dense hyaline fibrous tissue.

The patient made an uneventful postoperative recovery, but over a period of months her wheezing, dyspnea, and cough became worse. Endoscopic dilatation elsewhere gave only temporary relief. Finally it was suggested to her local physician that a course of corticotrophin (ACTH) be given; this she began in November, 1950, continuing on a small maintenance dose thereafter. Following this, there was definite improvement, so that by December, 1951, she was able to be a part-time teacher. In December, 1952, she was even better, although still markedly handicapped.

The second case has been reported by others.[17] In essence it concerned a 26-year-old woman who came to the clinic on Nov. 13, 1948, with a history that four years prior to that time she had had a cough, loss of weight, night sweats, and pain in the left side of the chest. These symptoms subsided on rest in a tuberculosis sanatorium, although tubercle bacilli were never isolated and the tuberculin reaction was negative. In August, 1948, she began to suffer from cough, dyspnea, orthopnea, and episodes of tachycardia. During hospitalization, physical signs varied from time to time, but in general it was felt that there was presumptive evidence of mitral stenosis in the sharp first sound with a Grade 1 systolic murmur at the apex associated with an accentuated pulmonic second sound. Accordingly, the patient was treated by digitalization and low intake of salt. After cardiac catheterization, she suddenly went into frank cardiac failure and died.

At post-mortem examination, a large, gray, firm mass with the consistency of cartilage was encountered in the region of the bifurcation of the trachea. Within the mass there was a spherical lesion 1 cm. in diameter; it was yellow gray and soft, and resembled a caseous lymph node. The mass had almost completely occluded the venous return from both lungs except for the right inferior pulmonary vein, which drains the right lower lobe. The consequent pulmonary hypertension had resulted eventually in acute right ventricular failure and death. Since there were scattered small granulomas in the lungs, it was felt that the mediastinal lesion was of granulomatous origin and that during the healing process a keloidlike reaction had produced the dense collagenous mass.

These cases illustrate the dangerous potential inherent in healing mediastinal granulomas. However, this faculty is not necessarily restricted to those

found in the mediastinum. In speaking of the nature of granulomatous reaction in general, Forbus[18] has stated that "the healing of the lesions may give rise to effects which are as dangerous as the progressing disease."

We do not know the relationship of this entity to tuberculous mediastinal abscesses and fistulas,[19, 20] since the tuberculous origin of such conditions has rarely been adequately established. This is illustrated in the following case.

A 32-year-old man came to the clinic on July 23, 1940, with draining osteomyelitis of the sternum. He had been without symptoms until five months prior to admission when he sustained trauma to the anterior part of the chest followed by soreness and, several months later, by painful swelling. Incision and drainage had been carried out by his home physician, but when the drainage persisted for two months, he came to the clinic. He was coughing up small, hard "stones" about the size of wheat grains, and the same material was draining from the wound. On July 27, 1940, surgical exploration of this infection, which had perforated the right upper part of the sterum just at the junction of the manubrium and gladiolus, was accomplished. A large pocket beneath and to the right of the sternum was unroofed and packed open. Smears of this "pus" were negative for acid-fast bacilli, as were guinea pig inoculations. No "sulfur bodies" were seen. Histologic sections showed an acute granulomatous reaction with epithelioid cells, many polymorphonuclear cells, and an occasional giant cell. This was interpreted as being compatible with tuberculosis. Subsequently the patient made an uneventful recovery, and one year later the wound was apparently well healed.

It was the opinion of our staff at that time that the foregoing sequence of events represented a mass of tuberculous mediastinal lymph nodes which had been in the process of healing by calcification when the process was interrupted by trauma. This in turn produced a "cold abscess" and eventually a fistula. We have not included this case in the present series, since the diagnosis was not established by thoracotomy; yet it illustrates another manner in which mediastinal granulomas may become complicated.

SUMMARY

Sixteen cases of mediastinal granuloma in which the diagnosis was proved at exploratory thoracotomy have been reported from one institution. This suggests that the condition is much more common than it is ordinarily thought to be. The majority of the lesions are cystic, are located in the right paratracheal region, and present a rather characteristic roentgenologic appearance. All bacteriologic studies in this series of cases failed to reveal a definite etiological basis. Factors justifying surgical excision of such lesions are presented.

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PERSISTENCE OF THE LEFT SUPERIOR VENA CAVA WITH COARCTATION OF THE AORTA

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PERSISTENCE of a left superior vena cava is a congenital cardiovascular anomaly which can now be recognized during life by angiocardiography and cardiac catheterization. Recently, eleven cases of persistent left superior vena cava were reported; seven cases had multiple cardiac anomalies with cyanotic type of congenital heart disease.[1] The case reported here, persistence of a left superior vena cava with coarctation of the aorta, is the first in which associated noncyanotic cardiovascular anomalies have been recognized in life. The coarctation was corrected by resection of the coarcted segment and end-to-end anastomosis of the aorta.

CASE REPORT

A 14-year-old schoolgirl (N. Y. H. No. 656161) was admitted to the hospital on Aug. 16, 1953, with the chief complaint of heart trouble of many years' duration. At 3 years of age, choreiform movements were suspected and because of a harsh systolic heart murmur, a diagnosis of rheumatic heart disease was made. The patient was put to bed for one month and allowed to resume physical activity gradually. Subsequently, when she remained well and was asymptomatic, she was allowed full activities. Recently she had mild anterior chest pain, dyspnea, and palpitation; a routine examination disclosed mild hypertension. Absence of pulsations and blood pressure in the lower extremities led to the diagnosis of coarctation of the aorta.

Physical examination revealed a well-developed and well-nourished white girl in no distress. The right arm blood pressure was 150/80; the left, 146/72; the leg pressures were unobtainable and there were no pulsatile leg vessels. The heart was not enlarged; A_2 was greater than P_2; and a harsh, Grade 4, systolic murmur was heard over the precordium transmitted to the right interscapular area. Palpable systolic thrills were present in the supraclavicular spaces. The electrocardiogram was normal and the chest x-ray examination showed no cardiac enlargement or abnormalities of the aortic arch. Rib notchings along the under surfaces of the right seventh and eighth and left fourth and fifth ribs were seen. Angiocardiography[2, 3] revealed a rudimentary persistent left superior vena cava (Fig. 1) and the site of the coarctation (Fig. 2).

At operation, on Sept. 2, 1953, the patient was placed on the right side and a generous posterolateral incision was made. The fourth left rib was partially resected permitting exposure of the aortic arch and descending aorta. The left superior vena cava was forward and entirely away from the operative field. The coarctation, as seen in Fig. 2, was about 1½ cm. beyond the origin of the left subclavian artery. A small area of narrowing was present, distal to the coarctation, but the aortic caliber became normal at the site of entrance of the first pair of intercostal arteries. The ligamentum arteriosum was not patent. The first two intercostal arteries on the left and the first one on the right were clamped and transected, permitting mobilization of the aorta. Clamps were then placed on the aorta and

From the Departments of Radiology and Surgery of The New York Hospital-Cornell Medical Center.
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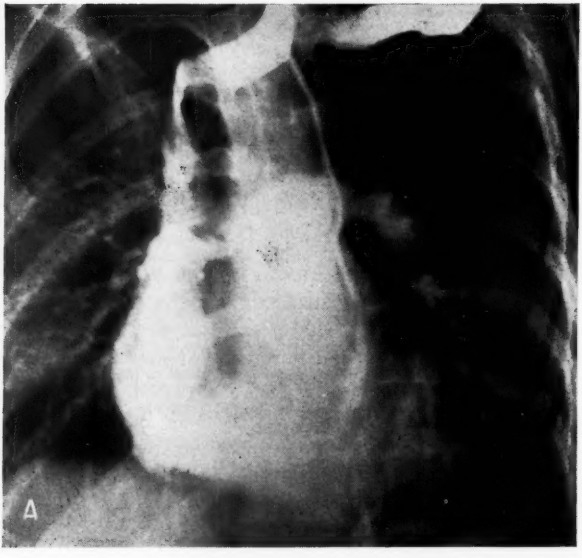

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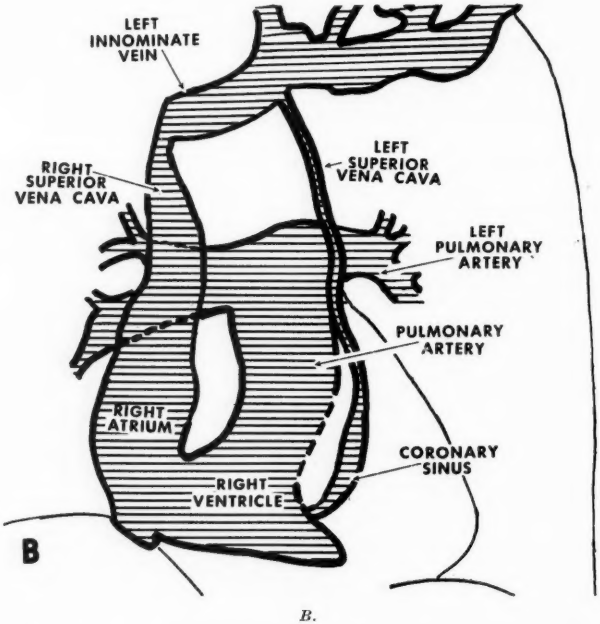
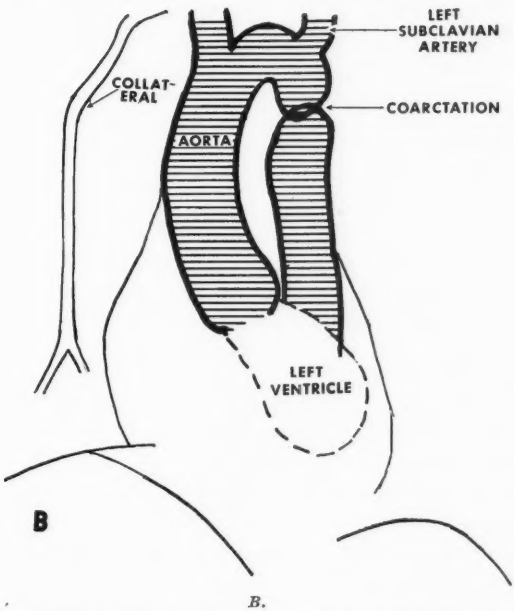


B.

Fig. 1.—Frontal angiocardiogram. *A*, Bilateral superior venae cavae, right heart, pulmonary artery, and branches opacified. The rudimentary left superior vena cava empties into the coronary sinus and right ventricle. *B*, Tracing.

A.



B.

Fig. 2.—Left oblique angiocardiogram. *A*, Left heart and aorta filled. The point of coarctation visualized just below the subclavian artery. *B*, Tracing.

subclavian arteries. Resection of the coarctation and end-to-end anastomosis of the aorta were easily accomplished. The distal aortic and left subclavian clamps were then cautiously released without any change in the blood pressure. Gradual release of the proximal aortic clamp and a 1,000 c.c. blood transfusion over a twenty-five minute period did not alter the blood pressure which remained between 135 to 140 systolic.

The postoperative course was uneventful and the patient was discharged home on the sixteenth postoperative day. Following operation the blood pressures varied between 130/70 and 148/90; the leg vessels became pulsatile with blood pressures of 140/105 in the right leg, and 125/100 in the left. The harsh precordial systolic murmur became soft in quality and the supraclavicular pulsations disappeared.

EMBRYOLOGY OF PERSISTENT LEFT SUPERIOR VENA CAVA

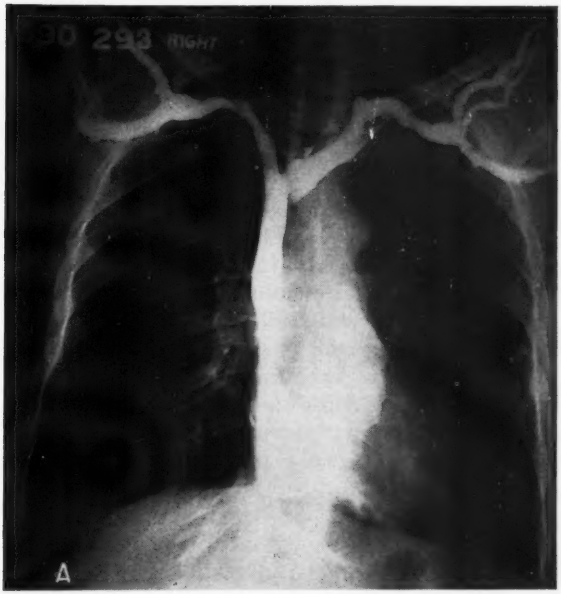
In early development, the cephalic portion of the embryo is drained by bilateral symmetrical right and left anterior cardinal veins. These join the posterior cardinal veins near the heart and form the right and left ducts of Cuvier which enter the sinus venosus. During the eighth week of fetal life, an oblique communication forms between the anterior cardinal veins and shunts blood from the left vein to the right. This vessel becomes the left innominate vein. The development of the left innominate vein is followed by atrophy of the left anterior cardinal vein. It normally persists as the first left intercostal vein. The left duct of Cuvier persists as the oblique vein of the left atrium which enters the coronary sinus. This last structure is derived from the left half of the sinus venosus. The right duct of Cuvier normally becomes the superior vena cava. The fully developed brachiocephalic veins forming the superior vena caval system in the adult are demonstrated in Fig. 3.

If the left innominate vein fails to develop, the left anterior cardinal vein persists and continues to drain the left brachiocephalic veins. In this situation it becomes the left superior vena cava. Since the left duct of Cuvier empties into the left half of the sinus venosus which ultimately becomes the coronary sinus, a persistent left superior vena cava drains into this structure.[1, 4-6] In our case (Fig. 1), the left superior vena cava persisted in rudimentary fashion while the left innominate vein developed normally.

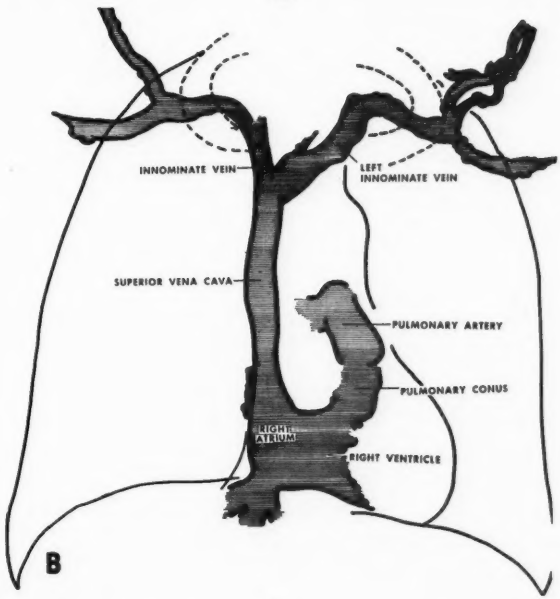
INCIDENCE AND CLASSIFICATION OF PERSISTENT LEFT SUPERIOR VENA CAVA

Sanders,[7] in 1946, on review of the anatomic literature, recorded 215 cases of persistence of the left superior vena cava and estimated the incidence to be 1:348 cadavers. Since then, many cases recognized by angiocardiography and cardiac catheterization have been reported.[1] The association of persistence of the left superior vena cava and aortic coarctation has been noted four times at autopsy and in one instance only the left superior vena cava without a corresponding right superior vena cava was found.[8] Our case is the fifth instance of the association of the two anomalies and the first to be recognized during life.

In a recent report persistence of the left superior vena cava was classified according to whether associated congenital cardiac anomalies were present or absent. Usually multiple cardiac anomalies were present producing cyanotic types of congenital heart disease.[1] This case is also unusual in that the combined lesions produced a noncyanotic type of congenital heart disease. All but



A.



B.

Fig. 3.—Normal frontal angiocardiogram of the superior vena caval system. *A*, Both arms injected simultaneously to show the anatomy of the brachiocephalic, innominate, and superior vena caval veins. *B*, Tracing.

one of the previously reported cases had bilateral superior venae cavae. Rudimentary intercommunicating innominate veins were often seen while a rudimentary left superior vena cava as in this case (Fig. 1) where most of the blood from the left brachiocephalic veins pass through the left innominate vein and into the right superior vena cava was encountered only once previously.[1]

COMMENT

Surgical correction of the aortic coarctation was not hampered by the presence of the persistent left superior vena cava. Contrary to the warning of Brown,[8] who thought the anomalous superior vena cava might complicate the operation, no difficulty in repair of the coarctation was encountered. Furthermore, in still another case, a large full-sized persistent left superior vena cava did not interfere with mitral valvulotomy for mitral stenosis.[1] Whereas, the embryological development of a persistent left superior vena cava is easy to understand, the theories of development of coarctation of the aorta are controversial.[9, 10] A direct relationship between the development of persistence of the left superior vena cava and coarctation of the aorta seems unlikely.

SUMMARY

The first case of persistence of the left superior vena cava and aortic coarctation recognized by angiocardiography during life is reported. The persistent left superior vena cava did not interfere with surgical correction of the coarctation of the aorta.

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THE USE OF FIBERGLAS IN PULMONARY TUBERCULOSIS

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THE past two decades have seen a gradual and progressive improvement in the treatment of pulmonary tuberculosis, particularly in the fields of chemotherapy and surgery. This advancement may be attributed to a number of factors, including improved anesthesia, improved knowledge of cardiopulmonary physiology, improved surgical techniques, chemotherapy, and certain significant advances in pre- and postoperative care.

Despite this improvement and advancement there still remain many patients in whom the prognosis remains poor and for whom the outcome is inevitably fatal if some other approach than the orthodox one cannot be devised. Attempts to solve this problem have taken on numerous aspects; however, the underlying principle has remained essentially the same, namely, some form of extrapleural or extrafascial pneumonolysis. This method of attack has provided certain advantages not inherent in other, presently acceptable, types of surgical approach, including pneumothorax, pneumoperitoneum, thoracoplasty, lobectomy, and pneumonectomy. These advantages include:

1. A sacrifice of a minimum of functioning "nondiseased" lung tissue.
2. A high degree of selective collapse.
3. A minimum of operative stages and consequent surgical trauma.
4. A minimum of interference with muscle balance in cases where muscle imbalance postoperatively may prove crippling to the patient (the younger age group especially).

The most irksome difficulty encountered in extrapleural pneumonolysis has been the management of the residual space and the development of infection within the surgical area. As a means of combatting the difficulties, various materials have been utilized as "filling substances"—gauze, muscle, fat, wire mesh, paraffin, air, saline solution, oil, and Lucite (Synonyms.—Crystallite, Vitarilic, Plexiglas). All have been employed, and to date the most satisfactory in our experience has been paraffin. However, this too has had its inherent difficulties and has all but been discarded. Most recently Lucite balls have enjoyed a virtual "field day," but with certain exceptions they seem to be disappointing. Their use as a permanent "plumbage" is still open to question because of the difficulty encountered in their ultimate removal, their propensity to migrate, and their ability to erode through great vessels, the trachea, etc. The use of a "sealed" Plexiglas bag as a permanent "container" has not yet won universal acceptance and has not been adopted in this Clinic.

From the State Sanatarium, Hamburg, Pa.
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In June, 1948, O'Neil and his associates presented their experimental findings in animals and human beings wherein Fiberglas wool and Fiberglas fabric were used. Their demonstration showed that a very minimum of tissue reaction occurred around the implanted Fiberglas mass when their recommended technique was followed. It therefore appeared from their studies that this substance presented a material sufficiently inert to merit serious consideration and an adequate period of trial in human patients.

The use of Fiberglas wool and Fiberglas fabric was undertaken at this Clinic in September, 1948, and since that time fifty-four patients have undergone this procedure.

In the early stages of the study, the classical technique for extrapleural pneumonolysis was followed, and the technique for applying the Fiberglas followed that described by O'Neil and his associates.

Among this group of patients, three developed infections in the plumbage space. One case of infection definitely followed cavity wall necrosis in an otherwise desperately ill patient. This resulted fatally. The remaining two cases could not be explained on any apparent basis. It was therefore concluded that the source of infection could well have come as a result of the interruption of the continuity of the mediastinal lymphatics, thereby opening avenues of infection into the surgical area.

In consequence of this conclusion, the extrapleural technique for creating the collapse was abandoned and the extraperiosteal (extrafascial) technique adopted. Following the adoption of the changed technique, one infection occurred. It was in a patient (age 38) who had recently undergone a radical mastectomy for carcinoma of the breast on the ipsolateral side. This occurrence therefore was not considered a contraindication to further use of the procedure.

It was felt that the extraperiosteal technique constituted an improvement and afforded the patient a reduced possibility of a complicating infection. There remained one possible difficulty, and this required the passing of considerable time to evaluate fully, the fate of the ribs following the removal of their periosteum. It was expected that they might undergo, at least, some degree of osteoporosis. This did occur and was therefore considered to constitute a decided disadvantage. Subsequently, using parallel incisions along the upper and lower margins of the ribs, the external periosteum was left in place.

We are not unmindful of the fact that the extraperiosteal technique has been employed heretofore under different circumstances (extraperiosteal pneumothorax) and has been quite thoroughly condemned. However, it is felt that the procedure has certain inherent advantages if the disadvantages can be overcome. If Fiberglas is inert, and indications at that time attested to the fact that it is, then a plumbage using that material would not create a dense fibrous capsule, its removal would be accomplished with ease, and the operative field would be available for some other procedure in the event the plumbage proved ineffectual. Such has been our experience to date.

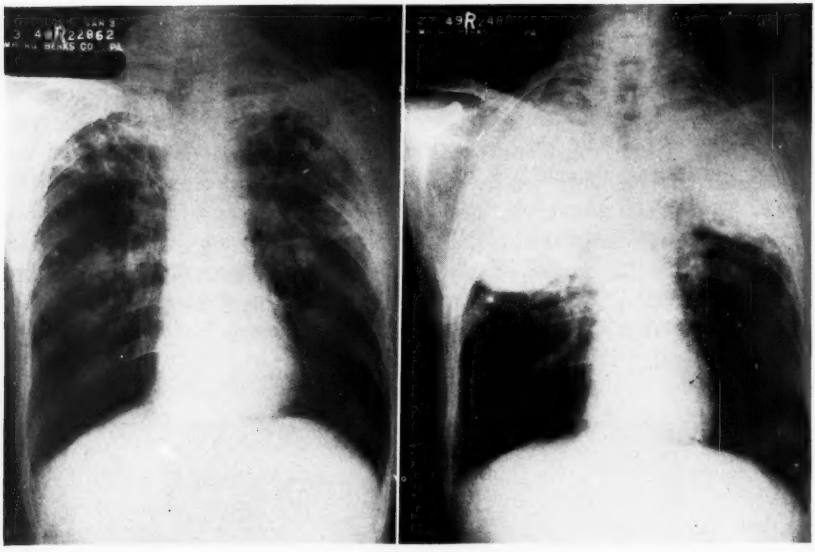
The advantages lie chiefly in the fact that the mediastinal lymphatics and the possible peripheral blood supply to underlying cavity walls are not disrupted, complete decollation of the apex need not be effected, and therefore the tendency of the apex to drop downward as in an extrapleural pneumonolysis does not become a factor. The management of the freed periosteum constituted a major consideration at the outset. At first the periosteum was formalinized to preclude bone regeneration, but later it was discovered that this precaution could be abandoned with impunity. Resection of the partially denuded ribs at a subsequent operation can be performed with a minimum of trauma and with the loss of an absolute minimum of operative time. Thus, should regenerated bone develop, and its removal become necessary, this may be accomplished with no greater trauma and in much less time than a revision (secondary) thoracoplasty.

A. *B.*

Fig. 1.—W. J. A successful unilateral plumbage collapse in a patient with a very limited respiratory reserve. At four-year follow-up, patient's condition still excellent.

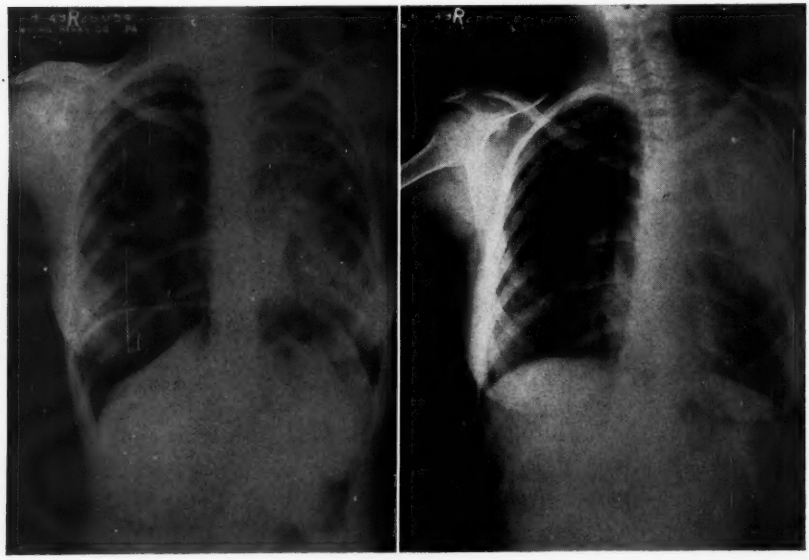
INDICATIONS

It is felt that surgical procedures of this type are not a substitute for thoracoplasty, pulmonary resection, or other definitive procedures, especially when a thoracoplasty or a resection, etc., can be performed without incurring the possibility of serious or undesirable complications. (Fig. 1.) In the present series the following were considered the predominant indications for either the extrapleural or the extrafascial plumbage:



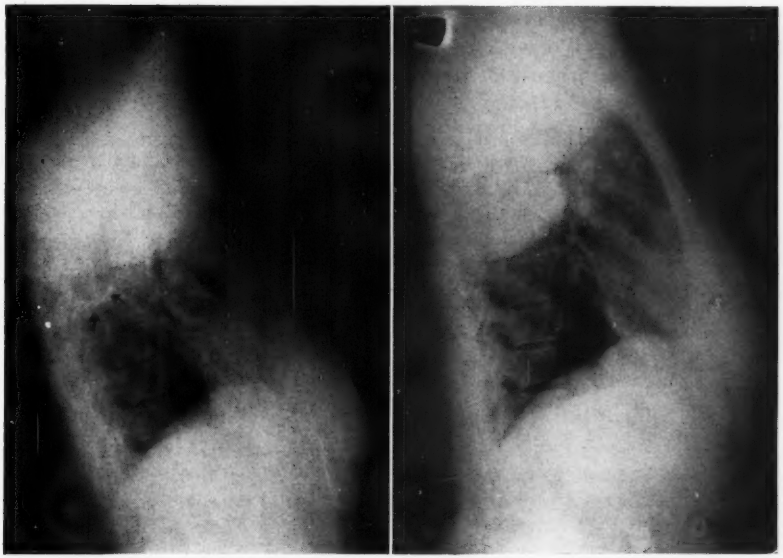
A. *B.*

Fig. 2.—W. Z. A successful bilateral Fiberglas plumbage collapse in a patient in whom a bilateral thoracoplasty of a satisfactory extent could not have been performed safely.

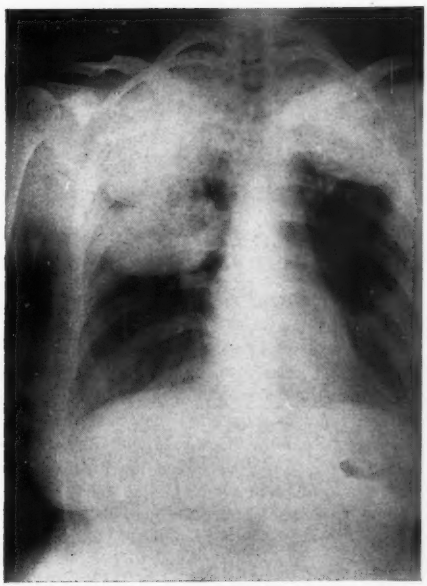


A. *B.*

Fig. 3.—F. T. A successful plumbage collapse in a 14-year-old child in whom a postthoracoplasty (seventh to eighth ribs) scoliosis would otherwise present a serious problem.



A. *B.*



C.

Fig. 4.—G. K. Illustrates case with second and successful implantation to "close" a cavity developing after and below the original collapse.

A. *Extrafascial.*—

1. Patients with bilateral disease where a thoracoplasty has been, or is planned for one side, bilateral thoracoplasty being considered undesirable because of the late discomfort to the patient or bilateral thoracoplasty being considered likely to result in respiratory insufficiency. (Fig. 2.)
2. Patients in whom a multiple-stage thoracoplasty is contraindicated because of a serious nonpulmonary complication such as cardiac disease.
3. Patients who because of advanced age are not considered good surgical risks for a multiple-stage operation. This frequently, but not always, includes patients over 60 years of age.
4. Young patients who without prolonged good orthopedic care might develop a consequent severe scoliosis if a multiple-stage thoracoplasty were to be performed. This group generally includes individuals below the age of 20 years. (Fig. 3.)
5. Patients who refuse the indicated type of operation, generally thoracoplasty, because of fear, cosmetic reasons, etc., and who may be salvaged and very possibly returned to society. (Fig. 4.)

B. *Extrapleural.*—

At the outset, eleven patients (one bilateral case) were operated on according to the standard extrapleural technique. Nine cases were entirely successful, and three patients developed infections in the extrapleural space. Prior to the development of these infections, the same criteria as were just described for the extrafascial operation were considered to comprise the indications for this procedure. However, following the perforation of the cavity in the one case, and the occurrence of infections in the two others, it was felt that patients having cavities over 2 to 3 cm. in diameter probably should not be subjected to this type of technique and, if so, only if the complete x-ray history could be obtained and convincing evidence obtained that the cavity in question had never been larger than that shown on the preoperative roentgen films.

MATERIAL

The Fiberglas* fabric, which is known as "116 cloth," is 0.004 inch thick and is of balanced Fiberglas 450½ yards, 60 ends per inch in the warp and 58 per inch in the fill. Each strand is formed of approximately 200 individual filaments. The average filament diameter is approximately 0.00022 inch. The Fiberglas wool is the Fiberglas superfine wool composed of glass fibers randomly oriented in a batt. All filaments in both the batt and fabric are resin free, and uncoated. Both batt and fabric are prepared preoperatively by boiling for forty minutes on four consecutive days and are delivered warm to the operating table. Should the quantity of the material delivered to the operating table be in excess of the amount required, the remainder may be spread thinly on a clean towel, dried, and reprocessed in like manner when subsequently needed.

TECHNIQUE

The procedure adopted in the extrapleural group follows the standard technique. With the patient lying in the lateral position, a curved periscapular incision is made.

*Supplied through the courtesy of the Owen-Corning Fiberglas Corporation.

The superficial and deep muscles are divided, the rib providing the optimum approach is selected (generally the third or fourth), and approximately a 4 to 5 cm. section is resected subperiosteally. The anterior periosteum is divided longitudinally, and a cleavage plane is developed in the plane of the endothoracic fascia. The lung is thus dropped away from the chest wall. An effort is made not to carry the dissection down the mediastinum beyond the point of the bifurcation of the great vessels. After the dissection is completed as planned, the area is well flushed with warm saline solution, the space is then lined with the Fiberglas fabric, and the bag thus created is filled with moist Fiberglas wool, applied in pledgets, snugly, but not packed. The bag being adequately filled, the excess fabric at the "mouth" of the bag is cut away, and the edges of the bag are then inverted and closed with a double cotton suture. The area is drained with a No. 14 or 16 Fr. catheter. The intercostal structures are closed around the catheter after 1 Gm. of streptomycin and 400,000 units of aqueous penicillin are injected. The remainder of the wound is then closed in layers. Interrupted cotton sutures are used for closure of the muscle and fascial layers, and the skin edges are approximated with a continuous surgical nylon, interlocking type, suture.

The extrafascial technique differs widely from the preceding. The incision employed is that used in a routine thoracoplasty as practiced in this Clinic. The ribs are approached, and two parallel longitudinal incisions are made in the periosteum along the upper and lower margins of the ribs, thus leaving a "strip" of periosteum attached to each rib. A subperiosteal dissection is carried out, still adhering to the usual thoracoplasty technique. The number and extent of the ribs thus denuded is determined preoperatively, so that the upper level of the collapsed lung approximates an imaginary plane drawn transversely across the intercostal muscles, membranes are divided anteriorly and posteriorly, and the apex is freed downward for approximately 2.5 cm. By blunt dissection the lung is freed extrafascially to the sternum in front, tapering transversely as dictated by the planned plane of collapse. Posteriorly, however, the lung is freed to the level of the heads of the ribs throughout the entire length of the zone involved in the collapse. If this is carried out satisfactorily, the mobilized lung will collapse completely along an approximately transverse plane. The placing of the plumbage follows exactly that described for the extrapleural operation. Similar drainage is used. Antibiotics are injected into the wound area and plumbage mass, and the wound is closed in layers, as previously described.

TABLE I. ANALYSIS OF DEATHS

Cardiovascular Disease	3
Diabetes	1
Pericardial effusion	1
Cor pulmonale	1
Progressing tuberculosis (uncontrollable)	4
Infection following cavity wall necrosis	1
Renal tuberculosis with miliary tuberculosis	1
Following contralateral tuberculosis	1
Carcinoma of breast	1
Respiratory insufficiency (after removal of plumbage 11 months postoperative)	1
Total	15 (27.77%)

RESULTS

The present series includes fifty-four cases, in which there have been fifteen (27.77 per cent) deaths from all causes, none directly attributable to the Fiberglas itself (Table I). However, one patient in the extrapleural group, who was already in a critical state, died as a result of an infection consequent to the necrosis of the cavity wall. Thirteen patients, 24.03 per cent (fourteen plumbages, 25.82 per cent), became infected (Table II). One died postoperatively following removal of the infected mass and the per-

formance of the necessary obliterative thoracoplasty. This death was attributed directly to an unrecognized massive pericardial effusion discovered at autopsy. Of the remaining forty patients, thirty-four (62.96 per cent) became sputum negative or have had an apparently satisfactory collapse on the plumbage side. There are, however, three patients in whom the sputum is still positive, but as a result of tuberculous lesions in the contralateral lung, or in areas of the same lung at a distance from the region under the plumbage. All these lesions have developed many months after an apparently successful plumbage collapse; two of these patients have subsequently undergone a successful total pulmonary resection, and in two it has been possible to collapse the cavity by an additional Fiberglas implantation (Fig. 4). One of the two remaining positive patients may, in time, be subjected to a pulmonary resection, because of a basal cavity which has developed after the original plumbage was instituted.

TABLE II. ANALYSIS OF INFECTIONS AND TREATMENT

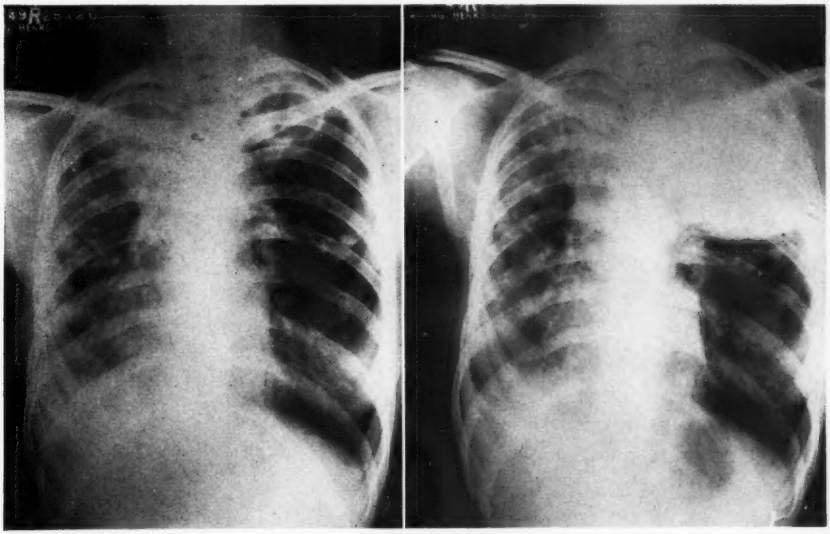
Total patients infected	13
Total plumbages infected	14 (1 bilateral)
Necrosis of cavity wall	1
Shortest period postoperative before infection	59.0 days
Next shortest period postoperative before infection	102.0 days
Longest period postoperative before infection	1,121.0 days
Average period postoperative before infection	403.0 days
Removal of plumbage and thoracoplasty and simple drainage	9
Removal of plumbage and pneumonectomy and thoracoplasty	2
Removal of plumbage and thoracoplasty with negative pressure suction	2
Decortication of middle and lower lobe and thoracoplasty (3 ribs)	1

COMPLICATIONS

For the purpose of comparison it is well to consider the extrapleural pneumonolysis (plumbage) and the extrafascial cases separately. During the early stages, our patients experienced a marked sensation of pressure within the plumbage area. This was found to be due to the fact that the Fiberglas wool will absorb a quantity of fluid and expand, especially if the wool pledgets are not sufficiently moist when placed within the Fiberglas fabric bag. This difficulty was overcome by placing a small (14 to 16 Fr.) fenestrated catheter drain in each created space for twenty-four to forty-eight hours. (No infections resulted from this practice.)

One patient experienced a small hemoptysis and some streaking of the sputum two weeks postoperatively. Although the bleeding was attributed at the time to the plumbage, the development of an additional tuberculous cavity, within four months, in another portion of the lung (subapex of lower right lobe), suggests the possibility of a different source of the bleeding other than the effect of the plumbage. Three patients developed infections in the extrapleural space, one because of perforation of the cavity (Fig. 5). In this case the Fiberglas was removed, the ribs were resected, and the area was drained. The patient was profoundly ill before the original operation. The added toxemia of the mixed infection and the insult of a second operation proved to be too great a burden upon the physiologic system, and the patient died. Two additional individuals developed a pure tuberculous infection in the extra-

pleural space. This was attributed to the possible fact that the lymphatics had been disrupted in the mediastinal area, thus opening possible channels of infection so that tubercle bacilli gained entrance into an area, not yet

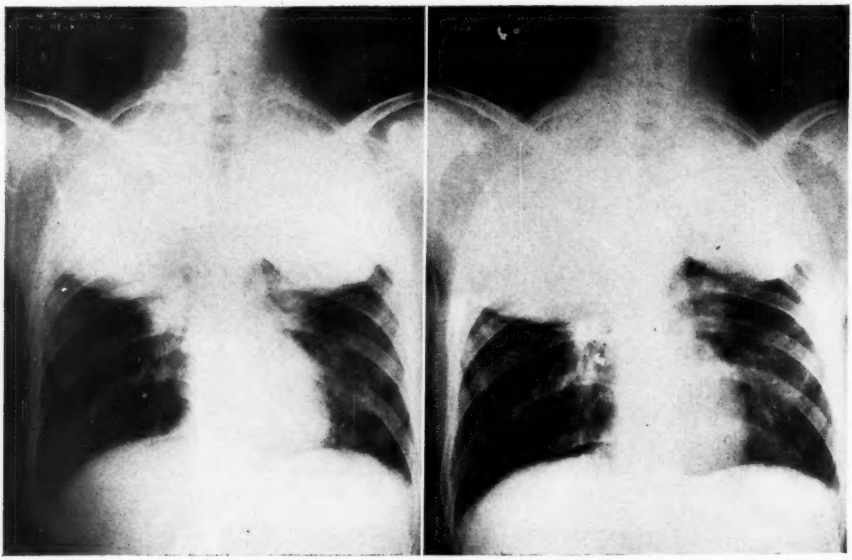


A. *B.*

C.

Fig. 5.—S. M. Necrosis of cavity wall in a poorly advised extrapleural plumbage; result was fatal.

thoroughly sealed off, where conditions were optimum for the culture and growth of the organisms. No other complications have developed directly as a result of this type of technique. However, it was felt that the hazards of such infections warranted virtual abandonment of the extrapleural procedure as such and the development of an alternate.



A. *B.*

Fig. 6.—T. L. *A*, Apparently successful bilateral collapse. *B*, Note increase in area of collapse on right side. This indicates increase in "fluid content" of the fiber mass, in this instance pus.

The extrafascial approach was therefore adopted and was used up to the time the Fiberglas plumbage was abandoned.

One instance of a pyogenic infection occurred in a patient who, fifteen (119 days) weeks previously, had undergone a radical mastectomy for carcinoma of the breast. In retrospect it is felt that either the operation should have been postponed or some other procedure should have been substituted. Likewise speculation suggests that patients in whom the soft tissues of the chest wall are scanty, as in the patient who is actually emaciated, performance of a Fiberglas plumbage or extrapleural pneumothorax, etc., should be undertaken with the utmost caution since a "stitch abscess" or an otherwise minor infection may well discharge infected material or organisms inwardly as well as outwardly, thus leaving the plumbage a likely site for gross infection.

Two additional patients in this group showed manifestations of profound respiratory insufficiency, and it was necessary to remove the plumbage in both instances. Following the removal of the Fiberglas, both patients showed rapid improvement which continued without further need for oxygen. Preoperative studies had indicated that we were justified in proceeding with these individuals, but "with caution." These studies, however, did not

suggest that either patient should have been as seriously hypoxic, postoperatively, as occurred, even in view of recognized limitation of diaphragmatic motion in one. The prognosis in both of these cases was thereafter considered grave, and the patients eventually died.

In addition to these three cases of extrafascial plumbage, and the two of the extrapleural group, there has been a total of thirteen (fourteen plumbages) patients who developed an infection in the plumbage area up to this time. We fear that there is a strong probability that still others will at some time follow the same discouraging pattern (Fig. 6).

DISCUSSION

It is no longer too early to evaluate this type of prosthesis. After a four-year follow-up, with findings at autopsy or on subsequent operation, it appears that Fiberglas is extremely nonreactive as originally claimed. It seems to be a reasonable assumption that very possibly in this lack of reaction resides the principal disadvantages of this type of prosthesis. The degree of reaction around the prosthetic mass is indeed minimal. The patient, after recovery, is completely comfortable and quite unmindful of its presence. So far there has been no difficulty encountered in removing the prosthetic mass, irrespective of the length of time it has remained in the individual patient. In certain cases it was initially believed that the Fiberglas could be removed and the lung re-expanded provided that such had been anticipated and the periosteum had been well formalinized at the time of the original operation. Later experience has necessitated a complete change of this optimistic view. In our cases, little or no bone re-formation occurred while the Fiberglas was in place, but when it was finally removed, and the overlying ribs were resected, solid re-formed bone has developed. Finally, there appears to be but limited osteoporosis or absorption of the partially denuded ribs except in the presence of an intercurrent infection. Infection, we feel, prevents the establishment of a new blood supply from the soft tissues of the chest wall following the adhering of these tissues to the bony substance. Perhaps the blood supply from the remaining periosteum becomes inadequate to meet the emergency demands imposed upon it by an infection. The advantages of Fiberglas over other substances, especially Lucite balls, initially appeared striking and obvious, but this advantage has been nullified by the apparent susceptibility of these patients to eventual infection. Paraffin has advantages over all the other substances yet suggested; however, having employed both materials, it is our conviction that the Fiberglas is far superior to paraffin in all respects except one—infection. Fiberglas, therefore, for this one reason, fails to provide the "tuberculosis" surgeon with a material long needed and long sought after. Its further use in this Clinic has been discontinued permanently or until a method of combatting this one miserable disadvantage has been discovered (Table III).

The reason for the high percentage of infections, which are both mixed tuberculous and pure tuberculous, has not been clarified, and we can only speculate as to the cause. It seems reasonable to speculate that the failure

TABLE III. SUMMARY TABLE C

Total cases		54
Total bilateral plumbages		6
Total patients infected	13	14
Total bilateral patients infected	1	
Total new tuberculous cavities developing		2
Total patients dead, all causes		14
Total positive sputum:		
a. Source unknown		1
b. Contralateral tuberculosis		
c. New cavities, same side (2 pneumonectomized successfully)		5
additional plumbages (same side)		2
d. Total remaining positive sputum		2
Gross total—successful plumbages (per se)		52
Net total—successful plumbages		34

of the Fiberglas to incite a tissue reaction precludes the production of a fibrous tissue that would otherwise infiltrate the Fiberglas mass; hence the mass "takes up" a quantity of tissue fluids that in turn provide a good culture medium for tubercle bacilli and/or other organisms at some future time. The Fiberglas plumbages that have been removed for reasons other than infection have all been quite moist and contain a generous supply of a clear straw-colored fluid (bacteriologically sterile). Futhermore, the underlying lung was freely movable with each respiratory cycle, and the surrounding capsule was exceedingly sparse or nonexistent (maximum depth of reaction 1 to 2 mm.). Re-formed bone in the extraperiosteal group of cases was generally absent even though no formalinization of the periosteum or removal of the intercostal structures was practiced at the time of the original operation.

SUMMARY

1. Fifty-four cases in which a Fiberglas plumbage has been performed are reported.

2. Fifteen (27.77 per cent) patients are dead from all causes.

3. Fourteen (26 per cent) have developed pyogenic, tuberculous, or mixed infections in the plumbage area.

4. Two patients have subsequently undergone pulmonary resection because of definite tuberculous cavities, and another is expected to become a candidate for a similar procedure.

5. Thirty-four (62.96 per cent) have remained satisfactory after a four-year follow-up, the last case having been performed thirteen months ago.

6. This procedure is being reported to show the hazards and not to recommend its adoption as an acceptable method of collapse therapy.

Acknowledgment.—We wish to express our sincere thanks to the Owen-Corning Fiberglas Corporation for supplying the materials used in this study and likewise to Mr. Morris, their representative, for his assistance and his many courtesies extended to us.

REFERENCE

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TRANSVERSOAXIAL TOMOGRAPHY AS A VALUABLE HELP IN ESTIMATION OF OPERABILITY OF PULMONARY CANCER

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THE determination of operability of lung cancer by means of the methods discussed in current available investigations is often very difficult. The degree of invasion and of fixation to the pericardium and to the pulmonary veins remains generally a complex problem which the radiologist tries to solve for the surgeon.

Yet, besides bronchoscopy, radiography is the essential means of diagnosis and investigation in lung cancer. The current anteroposterior and lateral films with their gross view of the tumor give us basic information. Frontal tomography helps us to clarify some interesting points: size, shape, involvement of a main or even secondary bronchus, and spreading bronchogenic lesions. Lateral tomography gives a better localization of the tumor. But none of the routine tomograms provides reliable information about the extension of the tumor to the mediastinum. Finally, angiopneumography, proposed by Neuhoff and Nabatof,[4] Ṣanty,[5] Sauvage,[6] and Weiss,[7] and discussed by Olivier Monod, gives, besides interesting anatomic precisions, indirect indications based upon the arterial images of the degree of operability. However, this method is neither always adequate nor free from risks.

Therefore, if we evaluate the present radiologic possibilities, we come to the conclusion that the simple films and tomograms enable us to diagnose and localize the tumor, to determine its size, its bronchial, and, to a certain extent, its arterial involvement. We agree also that angiocardiography can localize the tumor within the pulmonary arterial system and sometimes demonstrate exactly its accessibility. But there is as yet no solution to the problem of the extension to the mediastinum and pulmonary veins. It is therefore very difficult and often impossible to tell the surgeon whether or not he will find the mediastinum and the pulmonary veins free and whether or not the invasion of the pericardium prohibits surgery.

So we resorted to horizontal tomography hoping to find in its tiered sections what other methods of investigation could not give us, that is, the degree of mediastinal and paracardiac invasion. We thought that, whereas horizontal sections had helped Gernez-Rieux and Bonte[1] and Monod[3] in the diagnosis of tuberculous lesions, they might give us valuable information in pulmonary cancer.

Many intrathoracic organs, being cylindrical or cylindroconical, will be clearly outlined by the horizontal sections that transversoaxial tomography shows as sectional cuts perpendicular to their axes. In addition, the tumor itself, usually spreading excentrically, will appear like a section of a sphere just as well as on anteroposterior and lateral tomograms. Its spatial relationship to

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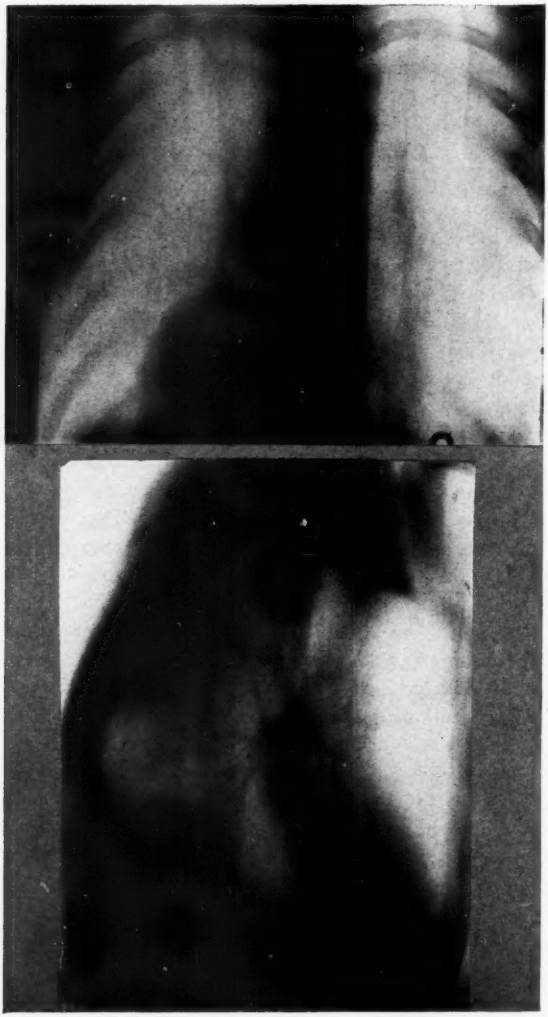
the mediastinal organs will be brought out clearly enough so that it will be possible to determine whether a plane of cleavage exists or whether there is extension to the mediastinal organs. Thus, whereas anteroposterior and lateral

A.



B.

Fig. 1, *A* and *B*. (For legend, see opposite page.)

tomograms fail to give us accurate precision as to the degree of operability of a bronchopulmonary tumor, horizontal tomograms provide us with most important additional information.

Having this in mind, we have used this method of study for over one year in all cases of pulmonary cancer we have had the opportunity to see and whose operability seemed questionable on routine tomograms. These patients were thoroughly studied radiologically, and the operative findings carefully correlated.

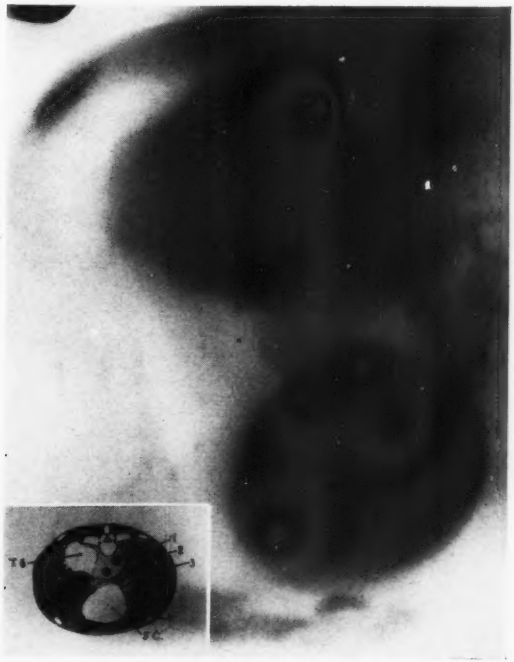
Of our series we shall present only three cases, ranging from an easily removable small tumor to a complicated and inoperable one.

CASE 1.—Mr. J. B. On the frontal tomogram (Fig. 1, *A*) a rounded, orange-sized mass appears in the right hemithorax. Its inferior outline fades into the cardiophrenic angle.

The lateral tomogram (Fig. 1, *B*) shows a rounded mass located within the right posterior paravertebral gutter. The limits of the tumor are confused with the posterior wall of the hemithorax.

The transversoaxial tomogram (Fig. 1, *C*) shows a mass located within the costovertebral groove, adhering posteriorly. A very distinct line of cleavage appears which separates it from the right edge of the spine. The mediastinum is free.

According to the horizontal tomogram, the resection is certainly possible. This was confirmed by surgical intervention.



C.

Fig. 1.—Case 1. *A*, Frontal tomogram. *B*, Lateral tomogram. *C*, Transversoaxial tomogram. *1*, Aorta; *2*, bronchus; *3*, pulmonary veins; *4*, rib; *5*, heart; *6*, tumor.

CASE 2.—Mr. A. H. On the frontal tomogram (Fig. 2, *A*) appears a big, orange-sized tumor between the upper and the lower lobes. On this film, it is impossible to tell whether the tumor can be removed or not.

Lateral tomogram (Fig. 2, *B*) gives no further information about the degree of operability.

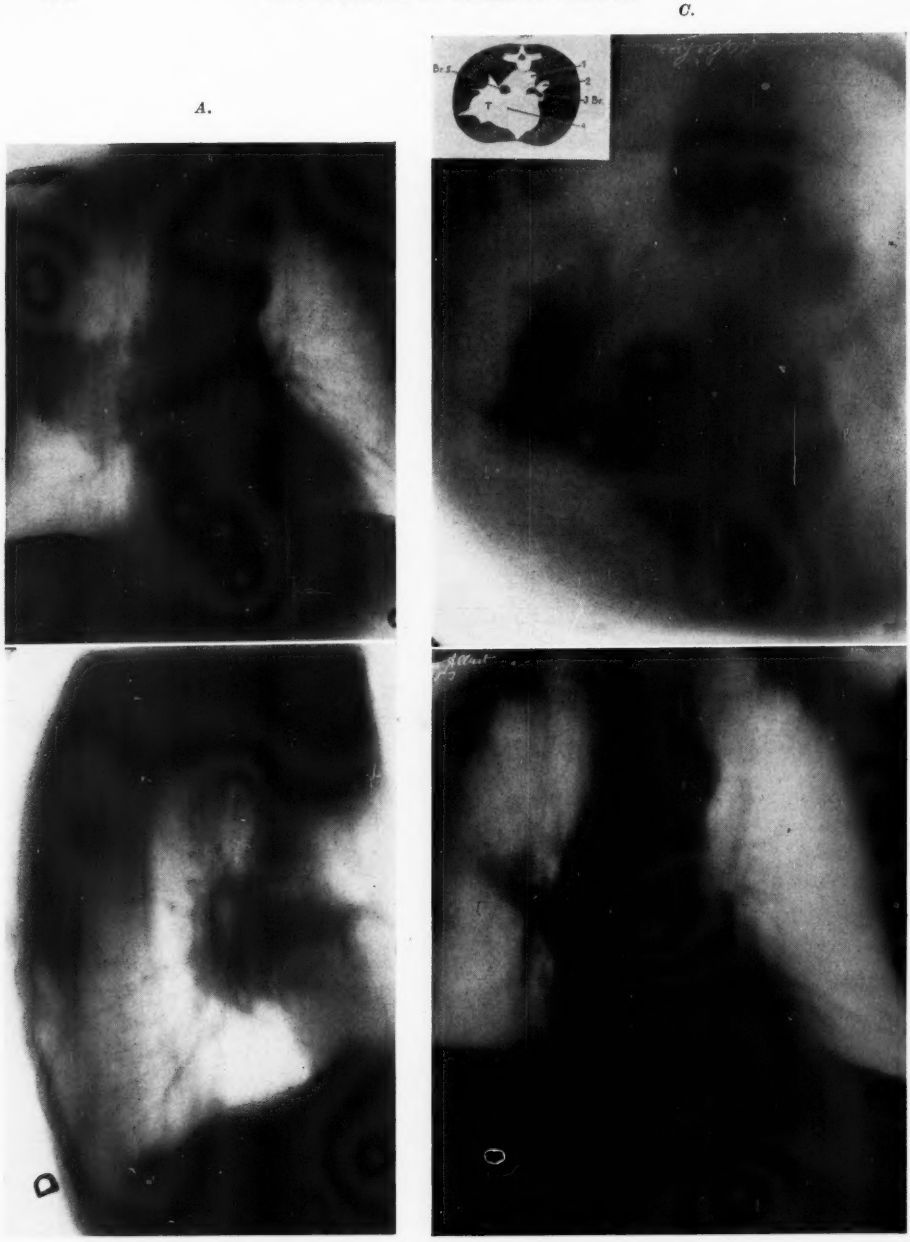
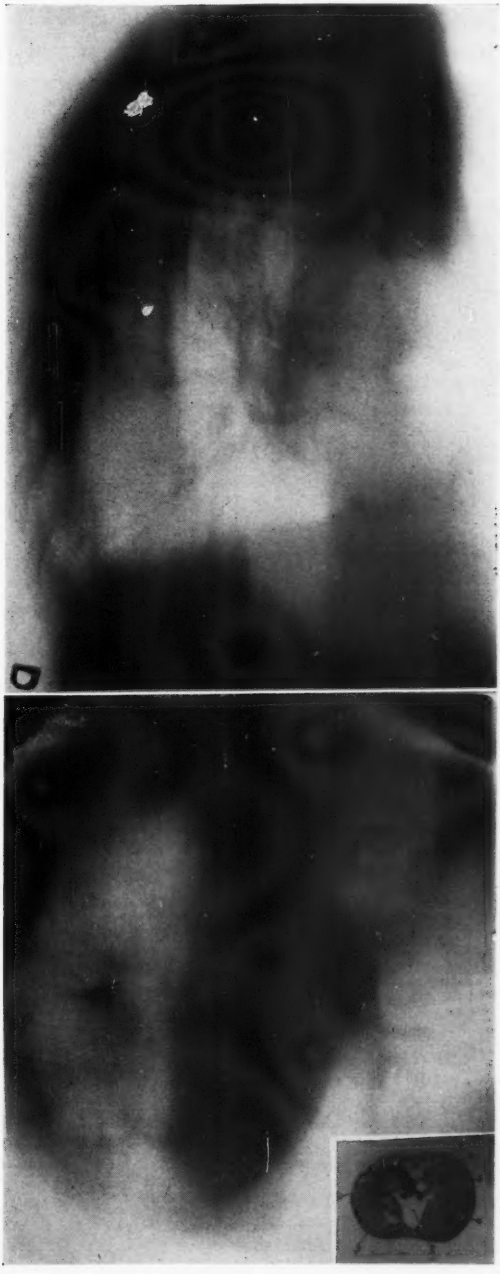


Fig. 2.—Case 2. *A*, Frontal tomogram. *B*, Lateral tomogram. *C*, Transversoaxial tomogram. *1*, Aorta; *2*, left pulmonary artery; *3*, left main bronchus and left upper lobe bronchus; *4*, heart and main vessels and tumor confused.

After radiotherapy. *D*, Frontal tomogram. *E*, Lateral tomogram. *F*, Horizontal tomogram. *1*, Rib; *2*, aorta; *3*, main right and left bronchus; *4*, left pulmonary artery; *5*, heart; *6*, tumor; *7*, main scissure.

E.



F.

Fig. 2, *E* and *F*. (For legend, see opposite page.)

Transversoaxial tomogram (Fig. 2, *C*) shows a big tumor mass within the right hemithorax. The outline is faintly visible; the tumor mass and the heart form one block in which no cleavage plane appears. The obvious conclusion is that the tumor is inoperable.

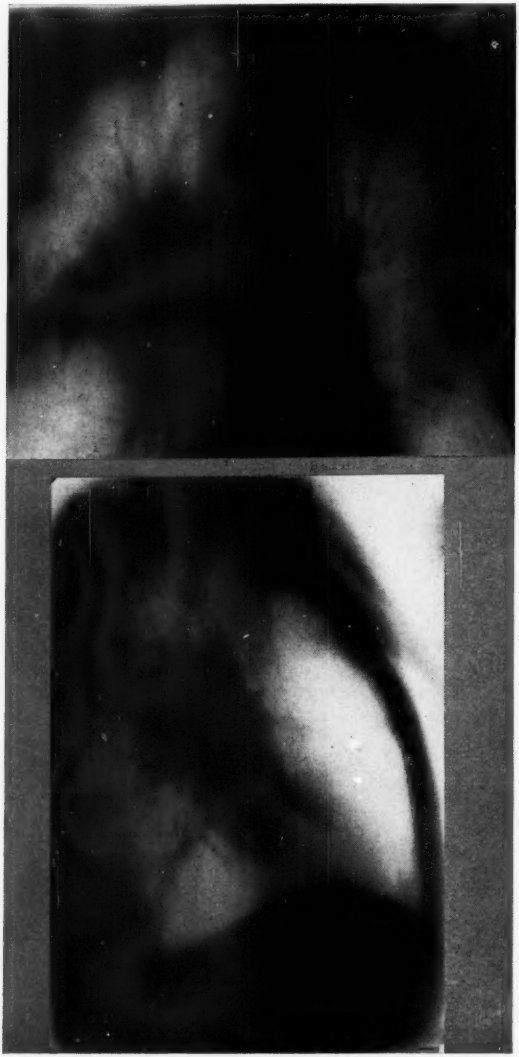


Fig. 3.—Case 3. *A*, Frontal tomogram. *B*, Right lateral tomogram. *C*, Horizontal tomogram. *1*, Aorta; *2*, left main bronchus; *3*, the right main bronchus is compressed; *4*, heart; *5*, tumor.

Inoperability was confirmed by thoracotomy.

After radiotherapy, new x-ray films show these findings: On the frontal tomogram (Fig. 2, *D*) there is an irregular tumor mass between the upper and middle lobe bronchi.

The lateral tomogram (Fig. 2, *E*) supplies little information. We see a small parahilar mass whose extension cannot be determined.

Horizontal tomogram (Fig. 2, *F*) shows the remains of the tumor on the right side of the heart with a definite space between the tumor and the heart. This distinct space establishes the possibility of operation.

The patient was reoperated upon, and a radical pneumonectomy with mediastinal lymph node resection was possible.

CASE 3.—Mr. T. K. The frontal tomogram (Fig. 3, *A*) shows the presence of a big tumor mass with an irregular outline. It occupies the lower part of the right upper lobe and infiltrates the mediastinal edge apparently over 8 to 10 cm.

The right lateral tomogram (Fig. 3, *B*) shows the tumor centered on the hilum, partial atelectasis of the posterior segment, and an invasion of the middle lobe.

On the horizontal tomogram (Fig. 3, *C*) we see a big tumor mass whose mediastinal outline fades into the cardiac shadow. The right main bronchus, strangled by the tumor mass, is reduced to a very thin slit. Behind it appears an atelectatic area. The mass obviously is inoperable. An exploratory thoracotomy confirmed the inoperability.

Fig. 3, *C*. (For legend, see opposite page.)

These few cases lead us to a first conclusion: If bronchoscopy shows the degree of bronchial invasion, angiocardiography the extension of the tumor to the arteries and consequently the possibility of their ligation, transversoaxial tomography brings a new element: the determination of the degree of involvement of heart, pulmonary veins, and mediastinum. Furthermore, as it also informs us about the extension of the tumor to the right pulmonary artery, it may in some cases be substituted for angiocardiography, which is not without risks.

Although it yields valuable information, horizontal tomography does not solve entirely the problem of operability of pulmonary cancer because it is limited by the anatomic disposition of the thoracic organs. It is easy enough to interpret the pictures of the right hemithorax where the trachea, the esophagus, the superior and inferior vena cava, and even the straight border

Fig. 4.

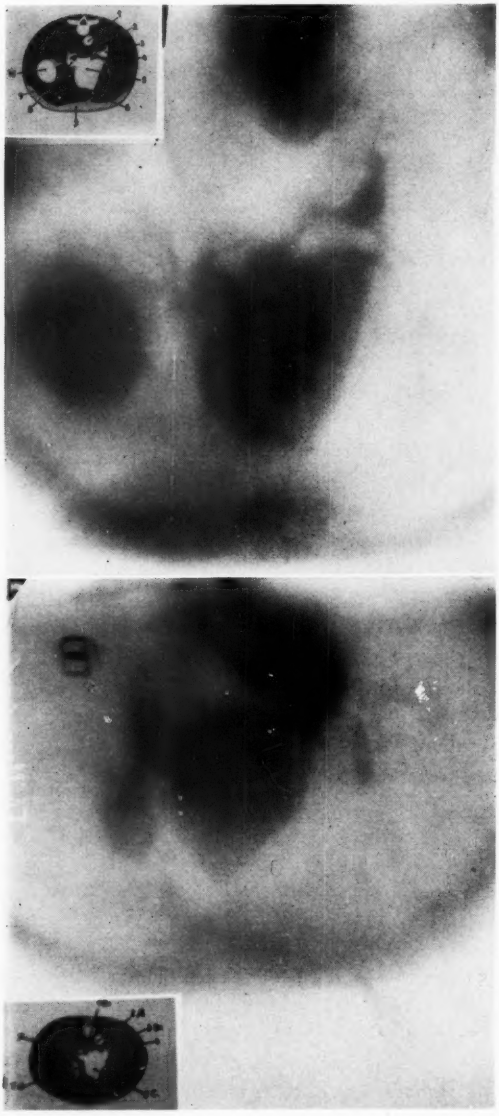


Fig. 5.

Fig. 4.—Case 4. *1*, Aorta; *2*, intermediate bronchus; *3*, left pulmonary artery; *4*, left main bronchus and upper lobe bronchus; *5*, heart; *6*, pericardial ligament; *7*, anterior chest wall; *8*, right pulmonary artery; *9*, tumor.

Fig. 5.—Case 5. *1*, Right main bronchus; *2*, aorta; *3*, left main bronchus; *4*, left pulmonary artery; *5*, heart; *6*, tumor; *7*, right pulmonary artery.

of the heart are sectioned perpendicularly to their axes and appear clearly outlined. However, the images of the left hemithorax are more difficult to identify.

Figs. 4 and 5 are two horizontal tomograms showing tumors of the right hemithorax, which will illustrate this difference when compared to the third tomogram (Fig. 6) showing a tumor in the left.

CASE 4.—Mr. E. M. The film (Fig. 4) shows a rounded, orange-sized mass in the right hemithorax. It is distinctly separate from the clearly visible right border of the heart. Both main bronchi and pulmonary arteries can be seen, the left main bronchus being cut just at the upper lobe bifurcation. Radiologically, the tumor is operable.

CASE 5.—Mr. T. On this film (Fig. 5) the tumor is in very close contact with the main trunk of the pulmonary artery. The main bronchi are well visualized. The right border of the heart is well demarcated. It is obvious that this is a borderline case for surgery, but the resection should be possible. Surgical intervention confirmed this diagnosis.

Fig. 6.—Case 6. Horizontal tomogram. *1*, Aorta; *2*, left main bronchus; *3*, tumor; *4*, plane of cleavage; *5*, heart; *6*, right main bronchus.

In the left hemithorax most of the sections will be different. There the curved left border of the heart and the oblique arch of the aorta masking partially the shadow of the pulmonary artery confuse the limits of these organs, and the various overlapping opacities obscure the outlines of the tumor on the horizontal tomograms. The sections show one single density where tumor and aorta, or tumor and heart, are difficult to dissociate. Case 6 is one typical instance.

CASE 6.—Mr. J. Z. The horizontal tomogram (Fig. 6), which cuts the thorax just below the carina, shows a very dense and opaque tumor mass spreading from the edge of the left main bronchus forward and laterally. On the right side of the tumor appears the outline of the heart, the right border of which is distinctly seen. On the left, however, heart and tumor are difficult to differentiate. Yet the section shows a slightly less opaque zone corresponding to the left border of the heart. This could be a cleavage plane which separates the heart from the cancer. The radiologist cannot tell for sure whether the operation is possible or not, and is inclined to consider the case inoperable.

The patient was operated on and the tumor found resectable. This case illustrated the difficulty in reading and interpreting horizontal tomograms in the left hemithorax.

We have tried to bring out the superimposed shadows by means of pneumomediastinum. By injecting air we hoped to separate and isolate the organs. The results have not been satisfactory. Some zones of clearing correspond, no doubt, to anatomic cleavage planes also found during operation, but there are others that pneumomediastinum is unable to bring out because the air cannot penetrate them. Furthermore, edematous, congestive connective tissues are also impenetrable to air, although they are no obstacle to surgery. This slight improvement in radiologic outlines is therefore of no appreciable value, and the contribution of pneumomediastinum no longer significant in the evaluation of operability in pulmonary cancer.

In conclusion, we believe that transverso-axial tomography will give precise information as to the tumor involvement of the vertical intrathoracic organs only, the transversal section of these being strictly horizontal. Information is less accurate where the organs have a development and anatomic disposition not following this rule: the ascending aorta, the arch of the aorta, and the left side of the heart. Valuable on the right side, transversoaxial tomography will be untrustworthy on the left. Its reading is still complex and its interpretation difficult. Technical improvement will in the future certainly make those tomograms easier to interpret in giving better outlines of tumors and mediastinal organs.

SUMMARY

1. The degree of adhesions of a pulmonary cancer to the mediastinum, to the pericardium, and to the pulmonary veins is always difficult to determine.

2. The frontal and lateral radiograms and tomograms give only fragmentary information.

3. Horizontal tomography, cutting transversally the intrathoracic organs with vertical axis, gives direct knowledge of the degree of fixation of the tumor to these organs. It indicates and outlines an eventual plane of cleavage between them and the tumor.

4. The importance of the information obtained is at least equal to that given by bronchoscopy about bronchial patency, or to that of the accessible length of pulmonary artery determined by angiopneumography. It is information about the relationship of the tumor mass to mediastinum, veins, and pericardium.

5. The value of this information, however, is not the same on both sides. Very reliable on the right, where it cuts only vertically disposed organs, horizontal tomography does not give very valuable information in the left hemithorax because of the oblique position of the heart and of the aortic arch, which appear as one with the tumor.

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BENIGN EPICARDIAL CYST

A Case Report

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PRIMARY tumors of the heart occur infrequently; survey of the available literature reveals less than two hundred cases reported to date. A slightly larger number of pericardial cysts have been reported; however, most of these pericardial cysts, according to their description, were derived from parietal pericardium. Only one definite reference to a cystic tumor of the epicardium (visceral pericardium) could be found.[1]

Fig. 1.—The epicardial cyst is visible in the right atrioventricular groove at the root of the pulmonary artery (×220, hematoxylin and eosin stain).

CASE REPORT

This 18-year-old, white, male laborer was admitted to the Robert Packer Hospital following an injury in an automobile accident. Despite decompression craniotomy, he died within twenty-four hours of admission. Past history was without significance.

Autopsy revealed the cause of death to be cerebral hemorrhage and diffuse pulmonary atelectasis. A purely incidental finding was a cystic structure, apparently a part of the

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epicardium, found in the right atrioventricular groove. This was located on the anterior aspect of the heart, and at the root of the great vessels (Fig. 1).

It measured 2.5 by 1.4 by 1.4 cm. The wall was smooth, thin, and transparent, and the fluid contained in the cyst was clear, colorless, and watery.

Microscopic examination revealed only a single layer of cells of the mesothelial type lining the cyst, supported by a few fibroblasts. Mesothelium of the epicardium was reflected onto the cyst anteriorly, and posteriorly it was separated from the pulmonary artery by a small amount of fibrous tissue (Fig. 2).

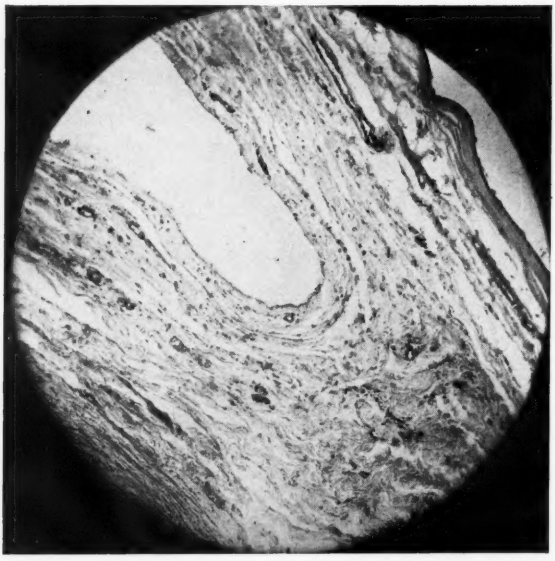

Fig. 2.—Photomicrograph showing mesothelial lining of cyst in right upper corner. On the left the epicardium is reflected over the cyst, while elastic fibers of the pulmonary artery are visible in the left lower corner (×220, hematoxylin and eosin stain).

DISCUSSION

As a rule the primary tumors of the heart are clinically silent; only two cases are on record which were diagnosed prior to death. No case of benign tumor has ever been diagnosed before death.[3] About 20 per cent of these tumors are malignant and the younger age group is chiefly affected.[2]

In our case this cystic tumor was not detected on x-ray examination of the chest nor was it suspected clinically. It is interesting to speculate as to what the eventual outcome of this cyst would have been had the patient survived.

SUMMARY

A case of benign mesothelial cyst of the epicardium is reported and discussed.

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INTRACARDIAC KNOTTING OF THE CATHETER IN HEART CATHETERIZATION

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SERIOUS complications of heart catheterization appear to be rare. The risk of intravascular knotting of the catheter has hitherto aroused little comment in the literature. Certain writers[1, 2] have pointed out the importance of avoiding looping and kinking of the catheter in its passage through the heart. A case was presented in which kinking of the distal end of the catheter caused it to be arrested at axillary level, and necessitated surgical intervention for its removal.[2] But a search of the literature has revealed no reports of more complicated coil or knot formation. We wish therefore to describe our mode of procedure in three cases of intracardiac knotting of the catheter.

It is sometimes difficult to guide the catheter from the right atrium to the right ventricle. Difficulties may also arise in its passage from the right ventricle up to the pulmonary artery. Protracted rotatory manipulation may be required before the catheter follows the desired direction. And in cases in which the structures concerned have poor roentgenoluceney, effective fluoroscopic control may not be easy to obtain during the manipulations. Constrictive pericarditis is such a condition. Here the pulmonary artery pressures are also of the greatest importance in assessing the patient's condition. During persistent attempts to guide the catheter into the pulmonary artery, fluoroscopic visualization of its position may easily be lost for a few seconds, which time may suffice to permit a knotlike looping.

The number of heart catheterizations performed at Sabbatsberg Hospital from Oct. 1, 1951, to Sept. 30, 1953, was 221. Most of the patients had sequelae of mitral disease or pulmonary disease. Twelve catheterizations, all by the same operator, were carried out on patients with constrictive pericarditis. Intracardiac knotting of the catheter which could not be freed by manipulation took place in three of these twelve examinations. Two of the knots formed in the same patient, before and after surgical treatment of the pericarditis.

When it became apparent that the catheter could not be disentangled within the heart, and when the maximum period of fluoroscopy was approached, the knots were tightened so as to make them as small as possible The catheter was then cautiously withdrawn from the heart under continuous fluoroscopic and electrocardiographic control. No difficulty was experienced at this stage. In one case a knotted No. 9 catheter could even be removed through the median cubital vein without administration of an anesthetic, and without undue discomfort to the patient.

Postoperative catheterization of the same patient was again complicated by the formation of a knot which could not be freed. On this occasion the knot, when withdrawal of the catheter was attempted, became wedged at the upper level of the axilla. Continuation of the attempt gave rise to considerable pain.

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A general anesthetic was given, and the knotted catheter was then easily withdrawn through the median cubital vein. Fluoroscopic visualization was very difficult in this patient. The appearance of the knot is shown in Fig. 1.

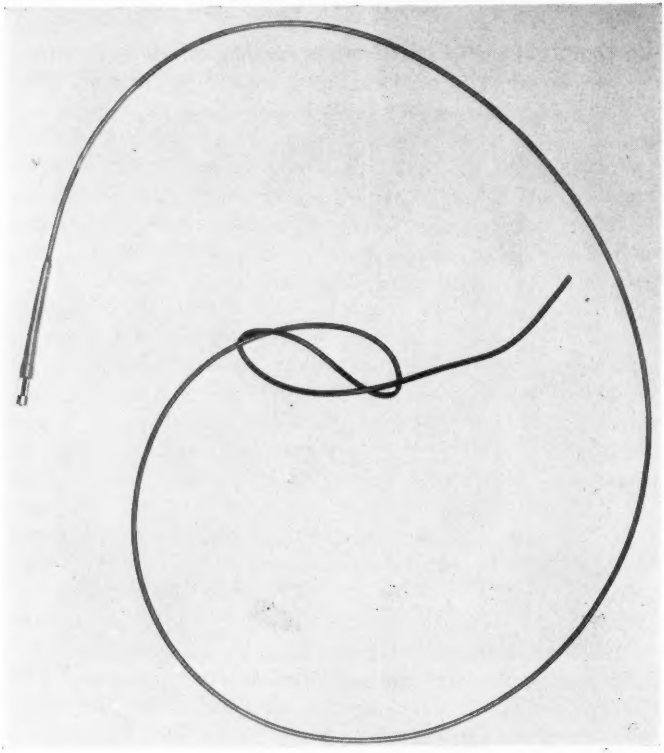

Fig. 1.

In the third instance a No. 9 catheter formed a large loop in the right ventricle. When the operator tried to straighten the loop, it rotated on its long axis, so that two more loops were added to that already present. The result was a small coil of catheter in the right atrium. All attempts to disentangle the coil were without effect. It was therefore cautiously drawn up through the superior vena cava and out of the thorax, until its passage was arrested at the level of the axilla on the left side. The patient was anesthetized and the catheter removed. But with it came the final portion of the basilic vein, which had to be excised The coil of catheter is shown in Fig. 2.

No cardiac arrhythmia was registered during the manipulations for catheter withdrawal in these cases. The patients suffered no aftereffects, and none of the catheterized vessels became thrombosed.

DISCUSSION

Constant effective fluoroscopy is essential for preventing intravascular knotting of the cardiac catheter. Coiling and looping must be avoided. If these

occur, an attempt should be made with all possible speed to straighten out the catheter. Should a knot form, withdrawal of the catheter would appear to be facilitated by anesthetization of the patient. This is probably because anesthesia relaxes the spastic state of the venous walls and simultaneously eradicates the associated pain reaction. A favorable relaxation of the shoulder and upper arm musculature is also achieved. The report shows that it is possible to remove the catheter without anesthesia, even when the knot is of fairly considerable dimensions.

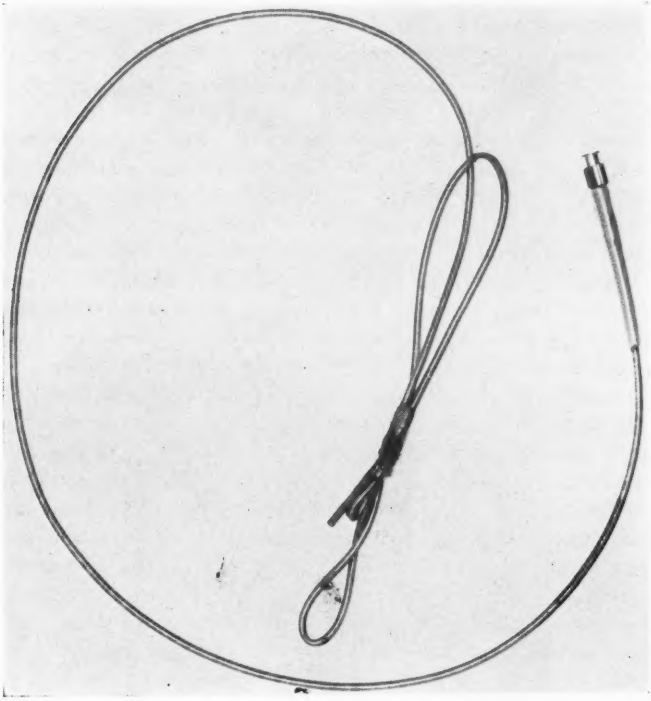

Fig. 2.

SUMMARY

Three of twelve heart catheterizations in patients with constrictive pericarditis were complicated by knotting of the catheter. Two of the three knots formed on different occasions in the same patient. In all cases the catheter was withdrawn through the median cubital vein. General anesthesia was necessary in two cases.

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CRYPTOCOCCOSIS OF THE LUNG

Report of Two Cases With Successful Treatment by Lobectomy

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CRYPTOCOCCOSIS or torulosis is a fungus disease which may be found in any part of the body but has a special predilection for the brain and meninges, where it is ordinarily fatal within six months About one-fourth of the 127 patients reviewed by Rateliff and Cook[1] showed pulmonary involvement either alone or as an initial stage of the disease before extension into the brain. Pulmonary disease appears to have a much better prognosis than cerebral disease, which represents the cause of death in most of the cases reported in the literature.

Considerable confusion of nomenclature is found in discussions of this fungus,[2] the most popular names for which are *Cryptococcus neoformans* and *Torula histolytica.* Other names are: Saccharomyces, sp., *Saccharomyces neoformans, Cryptococcus hominis, Torula neoformans, Cryptococcus histolyticus,* and *Cryptococcus meningitidis.* The disease is known as cryptococcosis, torulosis, Busse-Buschke disease, and European blastomycosis. It is not to be confused, however, with American blastomycosis, which is caused by *Blastomyces dermatitidis. Cryptococcus neoformans* is identified by Giemsa's stain and grows on Sabouraud's medium. It is a round organism with a thick-walled refractile capsule. It produces pseudohyphae and buds but does not produce mycelia. In contrast to yeasts, Torula ferments sugars little or not at all.

In early cases of pulmonary involvement with cryptococcosis the patients are usually relatively asymptomatic, with perhaps only a slight nonproductive cough, usually attributed to cigarettes. The diagnosis of torulosis in these patients is not suspected at that time, since only a localized area of pneumonitis is found on a routine chest film, which area is ordinarily suspected of being a tumor. It is only on pathologic examination of the resected surgical specimen that the correct diagnosis is made. While still in a curable stage, the fungi are encapsulated and not available for a positive laboratory test preoperatively by studies of either sputum or of bronchoscopic aspiration.

REFORT OF CASES

Case 1.—This 43-year-old grocery owner (J. M. P.) was discovered to have a "spot on his lung" on a routine tuberculosis survey film on July 1, 1952, at the Seattle Health Department. A similar film taken in 1951, as required annually of all food handlers, had been reported as negative. Examination at Barnes Veterans Hospital in Vancouver, Washington, showed an apparently healthy, afebrile man who weighed 173 pounds. He had had a chronic cough with one tablespoonful of yellow-white sputum daily for many years. There was a history of mild intermittent asthma since childhood and of "cat fever" while in the Navy in World War II. He had had acute exacerbations of his chronic bronchitis about four times yearly. His personal and family histories were negative for tuberculosis.

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Fig. 1.—Routine chest film showing asymptomatic lesion in first patient reported which proved to be a localized Cryptococcus infection.

Fig. 2.—Photomicrograph showing *Cryptococcus neoformans* in the involved segments of the resected right upper lobe.

Additional chest films taken in August, 1952, showed no change in the shadows seen on the film two months earlier. It still represented a 4 cm., fairly round mass seen in the fourth anterior intercostal space in the midaxillary line. Repeated sputum examinations were negative for tuberculosis on smear and culture. A bronchoscopic examination on Aug. 26, 1952, was essentially negative, as were the bronchoscopic aspirations examined for tumor cells.

An exploratory thoracotomy was performed on Sept. 2, 1952, under the assumption that the x-ray shadow might represent a malignancy. The fifth rib was resected, and inspection of the underlying lung showed a large, hard, nodular mass in the periphery of the right upper lobe which had not extended beyond this local area. Mediastinal lymph nodes removed from around the bronchi and trachea showed no tumor or frozen section. The peripheral mass was well localized and rubbery rather than stony hard, so a lobectomy was elected rather than a pneumonectomy, since considerable doubt existed regarding the presence of a true malignancy. Individual ligation technique was used on all of the blood vessels and the right upper lobe bronchial stump. A modified thoracoplasty was performed at the same operation with removal of the second, third, and fourth ribs in addition to the fifth one previously removed. Two intercostal thoracotomy tubes were inserted in the pleural space and connected to an empyema bottle with a water seal. The tubes were completely removed six days postoperatively following an uneventful course with complete re-expansion of the remaining lung to fill the pleural space.

Pathologic examination of the surgical specimen showed a solid granulomatous lesion limited to the periphery of the right upper lobe containing large numbers of round organisms with a thick-walled refractile capsule identified by the pathologist* as *Cryptococcus neoformans.*

The diagnosis of cryptococcosis came as something of a surprise and incited another series of sputum examinations without the finding of any evidence of fungi on smear or culture. The usual course of 800,000 units of penicillin and 1 Gm. of streptomycin was given daily over a period of two weeks, and the patient was discharged about three weeks postoperatively, having been completely afebrile during the previous two weeks. Outpatient examinations failed to show any evidence of disability or recurrence eighteen months postoperatively.

CASE 2.—This 31-year-old salesman of metal products was discovered to have a paramediastinal shadow on the right lung in the region of the right middle lobe on a tuberculosis survey film in April, 1953. He had lived in Portland, Oregon, during the previous four years after leaving Oakland, California. A diagnosis of pneumonia had been made elsewhere after a negative sputum examination for tuberculosis was obtained. Despite two months of intermittent treatment with Aureomycin, his temperature of around 100° F. daily persisted, and the pain in his right chest gradually increased. During this period of treatment, the right lung shadow tripled in size, associated with progressive weakness, until he was unable to work by mid-July, when he came under my care.

A bronchoscopic examination on July 24 was completely negative, as was the pathologic examination of the aspirated secretions for tumor cells. The possibilty of a malignancy or fungus disease was considered, and an exploratory thoracotomy was performed on Aug. 3, 1953. Examination at this time showed a firm, rubbery consolidation involving the anterior portion of the right upper lobe and the entire right middle lobe, and extending across the fissure to include part of the right lower lobe. Large rubbery lymph nodes were present in the hilar area. Frozen section of a biopsy showed only a chronic inflammatory process. A total right pneumonectomy was performed, including the hilar and mediastinal nodes.

Pathologic examination of the surgical specimen showed most of the lung structure in the granulomatous areas to be obliterated by an inflammatory process which was composed essentially of isolated islands of tissue with doubly refractile bodies within them, some of which showed budding. A diagnosis of torulosis was made on the basis of the pathologic sections as well as the fresh smears with special stains.

*Dr. Jacobson.

The postoperative course was uneventful with the exception of a transient diarrhea. The customary 800,000 units of penicillin and 1 gm. of streptomycin was given daily until his discharge on the fourteenth postoperative day. Undecylenic acid was started prophylactically by mouth as soon as the diarrhea subsided, by the tenth postoperative day, and was continued prophylactically using 8 gm. daily for two months. Actidione was reserved for treatment of any proved reactivation. No recurrence of his disease was noted on his last examination six months postoperatively.

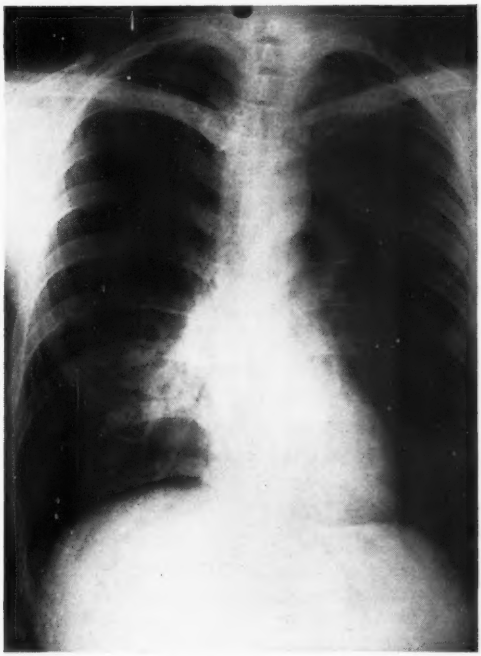

Fig. 3.—Chest film of second patient demonstrating lesion in right lower lung.

DISCUSSION

Cryptococcus infections resemble cancer in that they are amenable to surgical treatment as long as the infection remains localized in part of one organ, but as soon as it has extended into several systems, especially the brain and meninges, it is no longer a surgical problem. Cryptococcosis confined to one portion of lung seems especially suitable for surgical treatment, although the diagnosis is usually obscure before operation and the tendency is to think first of cancer.

A number of chemicals and antibiotics have been tested experimentally against Cryptococcus organisms with somewhat variable results, which have been universally better in vitro than in vivo, apparently because of inactivation of the drugs by human blood elements. Sulfonamides were thought at one time to represent the most satisfactory medical treatment of pulmonary or cerebral torulosis.[3-7] Animal experimental work failed to indicate a satisfactory

response of this disease to any drug or antibiotic, with the exception of the work of Reilly and Artman,[5] who concluded that sulfadiazine and streptomycin would prolong the life of white rats but would not cure them. No cures have been attributed to iodides, which have long been recommended for fungus diseases of all types. Taber[8] stated that until an antibiotic more specific for Cryptococcus is found, iodides might even be contraindicated. Johnson and associates[9] claimed that of four theosemicarbazones tested in vitro, bromothiazone proved the best. Klingman and Weidman[10] tested fatty acids, napthoquinones, antibiotics, and carbamide derivatives, concluding that actidione is the best in vitro, but that blood inactivates all of them and that theocarbonates are best in vivo. They recommended hyperpyrexia, holding the patient at 40° C. for six days, but no reports are available of any patient tolerating that temperature for the full period of treatment. Miller and associates[11] claimed that stilbamidine does not effect the clinical course of cryptococcosis.

Most recent clinical reports favor the use of actidione as being the best antibiotic available, even though it is not very effective. Actidione is an antifungal antibiotic prepared from *Streptomyces griseus* and represents a forerunner of streptomycin. Wilson and Duryea[12] reported a patient who was cured of *Cryptococcus meningitidis* for twenty months following a six-month course of actidione with 40 mg. each day intravenously. Carton[13] reported four patients treated with actidione, of whom two were dead and two alive, one of whom was considered cured. He also reviewed the literature and found most of the ten patients to have died who were reported as having been treated with actidione.

Hopkins and Murphy[14] reported a case of systemic spread of blastomycosis following resection arrested with undecylenic acid. Although American blastomycosis and cryptococcosis or European blastomycosis are not the same disease, long-chain fatty acids have been reported as beneficial against several varieties of pathogenic fungi and may be useful in treating cryptococcosis.

Dormer and associates[15] in 1945 reported a lobectomy for cryptococcosis followed later by a fatal spread to the central nervous system. Froio and Bailey[16] reported a five-and-one-half-year asymptomatic postoperative observation period following a lobectomy for localized pulmonary cryptococcosis in a 19-year-old man. Palmrose and Losli[17] reported a segmental lobectomy for torulosis followed by death from cerebral involvement four years later. I was involved with several subsequent operations on this patient and I wonder whether a whole lobectomy rather than a segmental one would not have provided a wider margin of normal tissue and longer period of survival in this case.

McConchie[18] of Australia reported pulmonary resections in three patients with pulmonary cryptococcosis since 1949, but both the case histories and periods of postoperative observation seemed quite brief. One patient still had untreated cerebral torulosis and another a contralateral pulmonary lesion when reported. No medical treatment was mentioned in any of the patients.

Over 200 cases of cryptococcosis have been reported, but of these, surgical resection of involved lung tissue has been performed in only eight patients, including the three reported from Australia. The two patients reported here were still living and well when last examined.

CONCLUSIONS

1. Cryptococcosis is a relatively rare disease, with only slightly over 200 cases being reported in this country.

2. Involvement of the central nervous system represents the most frequent location and cause of death.

3. Pulmonary involvement occurs before or associated with cerebral involvement in about one-fourth of the patients.

4. Pulmonary resection represents the most logical treatment of this disease when limited to a local area. Eight such resections have been reported.

5. Medical treatment of cryptococcosis has been very unsatisfactory, although sulfonamides and actidione have produced the most favorable reported results.

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PULMONARY TELANGIECTASIA: REPORT OF CASE PROVED BY PULMONARY BIOPSY

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IN THE past decade, congenital arteriovenous communications or shunts in pulmonary circulation have been recognized more frequently than formerly as a cause of cyanosis. A number of terms have been applied to such circulatory shunts including "pulmonary arteriovenous aneurysm," "arteriovenous fistula," and "cavernous hemangioma of the lung." In cases where the lesions are multiple, the descriptive term "congenital pulmonary telangiectasia" is probably preferable.

Undoubtedly, increasing interest in these lesions has paralleled the recent advances in diagnosis and surgical treatment of cyanotic heart disease. In 1897 Churton[3] first identified a pulmonary arteriovenous fistula at autopsy, and twenty-one years later Wilkens[21] reported a similar post-mortem observation. The first-known ante-mortem diagnosis of arteriovenous fistula of the lung was made in 1939 by Smith and Horton,[16] who accurately correlated the symptoms and diagnosis. Sloan and Cooley[15] recently reviewed eighty-five reported cases and added nine more from The Johns Hopkins Hospital. Several later reports bring the total published cases to more than 100.[2, 5, 6, 11, 17, 18]

The findings in a typical case of pulmonary arteriovenous fistula include cyanosis of varying degree, polycythemia, clubbing of the nails, and the presence of a normal heart. Demonstration of a continuous humming murmur on the surface of the chest may localize the point where a large fistula is in proximity to the rib cage. Radiographic examination usually reveals a tumefaction of homogeneous density of variable size and shape and in continuity with hilar vascular shadows. Laminagraphic studies may be useful in revealing the connection between the lesion and the pulmonary vascular tree, but angiocardiography is the most helpful technique available to define the true nature of such lesions.

Recently we observed a moderately cyanotic patient in whom the diagnosis of pulmonary arteriovenous fistula was suspected from the history and clinical findings, but the diagnosis was not established by radiographic methods including angiocardiography. The diagnosis in the case was verified by exploratory thoracotomy and biopsy of the lung. To our knowledge, this is the first case of suspected multiple pulmonary telangiectasia in which the patient was actually submitted to thoracotomy for the purpose of establishing the diagnosis by pulmonary biopsy.

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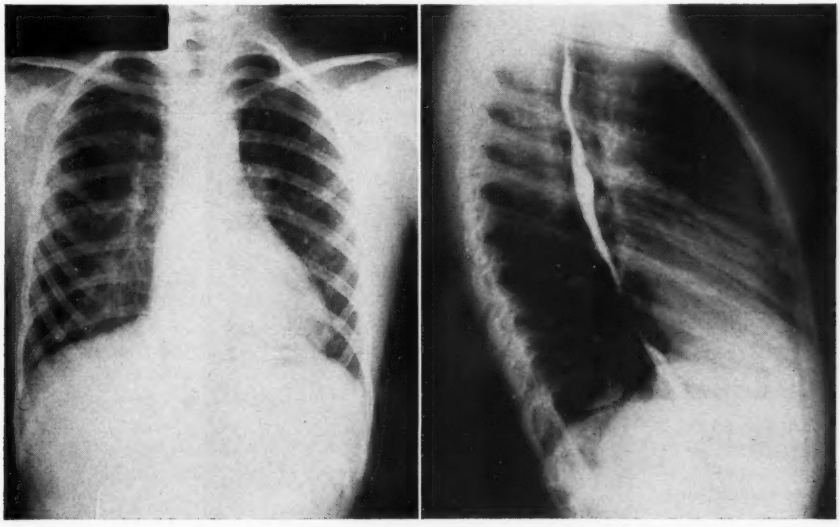
Fig. 1.—Photograph of patient showing Grade 2 to 3 clubbing of the finger and toenails which accompanied moderate cyanosis.



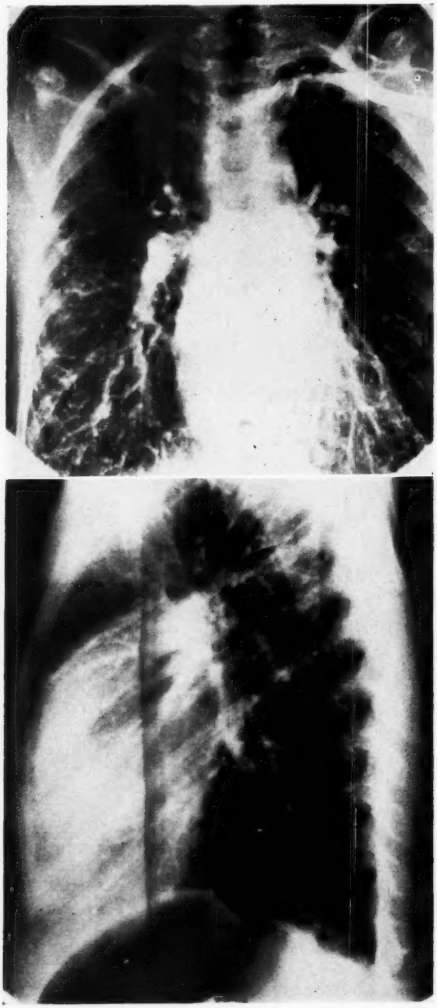
A. *B.*

Fig. 2.—Roentgenograms of the chest made in the posteroanterior (*A*) and right lateral (*B*) projections showing relative prominence of vascular markings in the lung bases and no abnormality in the heart and great vessels.

REPORT OF A CASE

M. R. V., a 7-year-old white girl, was admitted to the Methodist Hospital on Sept. 23, 1953, because of mild dyspnea which had gradually increased during the preceding eighteen months. Except for occasional mild infections of the upper respiratory tract, she had been in good health. About seven months prior to admission, her aunt, a registered nurse, noticed clubbing of the patient's nails (Fig. 1) and mild, but increasing, cyanosis which tended to appear after strenuous exertion.

A.



B.

Fig. 3.—Angiocardiogram in the anteroposterior (*A*) and left lateral (*B*) projections showing normal circulation of contrast medium through the pulmonary arteries. Vascular markings in the lung bases appear more prominent than in the upper lobes, and there is an irregular beaded appearance in the arteries of small caliber.

The patient, an only child, weighed 7 pounds, 6 ounces at birth. At 25 days of age she received radium treatment for a small hemangioma on the back, and when she was 1 month old, a raised hemangioma measuring 2 cm. in diameter was excised from the upper lip. Several smaller hemangiomas of the trunk and extremities had persisted since shortly after birth. There had been no episode of epistaxis, hemoptysis, or other hemorrhagic tendency, nor any evidence of abnormal development until appearance of the dyspnea, cyanosis, and clubbing of the nails. Numerous examinations by a referring physician including bronchograms and careful fluoroscopy failed to reveal any cause for these symptoms and signs.

The patient's mother, aunt, maternal grandmother, and a great aunt, as well as members of the father's family, all had hemangiomas.

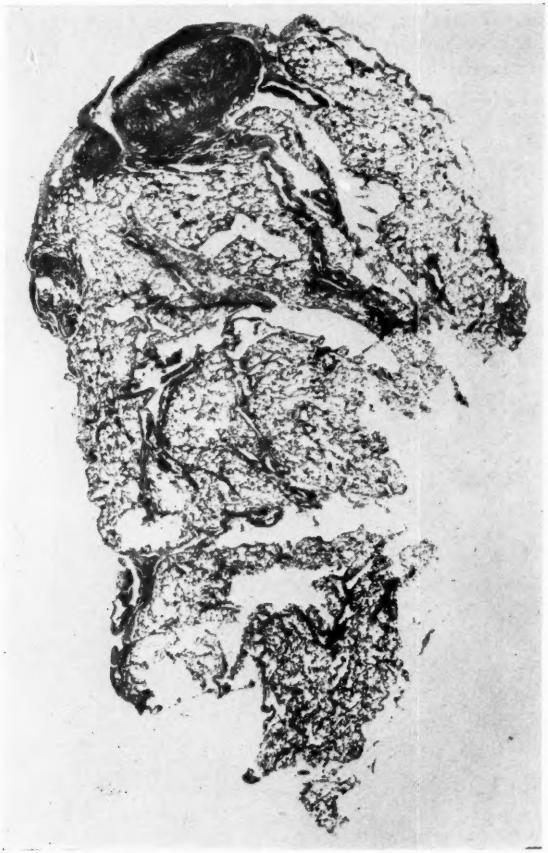
Fig. 4.—Photograph of the left lung made at thoracotomy showing the surface of the posterior segment of the lower lobe and several dark telangiectases or minute arteriovenous aneurysms.

Physical examination on admission revealed a well-developed, well-nourished, happy, alert, and apparently healthy girl. She had slight generalized plethora, 1 plus cyanosis, and 2 to 3 plus clubbing of the fingers and toenails (Fig. 1). The scars on the lip and back had healed, and several small flat hemangiomas were seen on the extremities and trunk.

Pulse rate was 106 beats per minute with sinus arrhythmia. Systolic blood pressure was 90 mm. Hg and diastolic pressure 50 mm. Hg. The heart was not enlarged, and no murmurs were audible. The pulmonary second sound was slightly accentuated and split, and the aortic second sound was normal. No bruits were elicited over the pulmonary fields. The remainder of the physical examination revealed no abnormalities.

Laboratory examinations revealed a red blood cell count of 5,610,000 per cubic millimeter, hemoglobin 17.4 Gm. per 100 c.c., and leukocyte count 15,750 per cubic millimeter

with 83 per cent segmenters, 5 per cent band forms, 5 per cent lymphocytes, 2 per cent monocytes, and 1 per cent eosinophils. A sample of femoral arterial blood was found to have an oxygen saturation of 81.4 per cent. Urinalysis yielded a specific gravity of 1.020, no protein or sugar, and 10 to 15 leukocytes per microscopic high-power field.



A.

Fig. 5.—Photomicrographs of section of pulmonary biopsy. At low magnification (*A*) there are visible at least three subpleural arteriovenous aneurysms measuring 2 to 4 mm. in diameter, and the deeper pulmonary parenchyma appears normal. At higher magnification (*B*), foci of angiomatous proliferation of mature type are revealed.

Fluoroscopy of the chest revealed the heart to be of normal size and configuration, with normal pulsations. No unusual pulsations were observed in the hilar region, but pulmonary markings appeared accentuated, particularly in the base. Roentgenograms of the chest exhibited accentuated peripheral pulmonary markings but failed to demonstrate any isolated pulmonary lesion (Fig. 2). Angiocardiogram demonstrated normal circulation of the contrast medium through the heart and great vessels without evidence of abnormality. Vascular markings were more prominent in the bases of the lungs than in the upper regions, but no area of pooling of the contrast medium was evident. Most of

the vessels, however, presented a curious beaded appearance extending out into the peripheral pulmonary zones and involving the arteriolar divisions (Fig. 3).

The electrocardiogram revealed sinus tachycardia (120 beats per minute) and right axis deviation (plus 135 degrees) with a vertical position of the heart and no evidence of ventricular hypertrophy.

On Sept. 26, 1953, under ether anesthesia, exploratory thoracotomy was performed for the purpose of pulmonary biopsy through a short left posterolateral intercostal incision. The pulmonary surface appeared pink and glistening. As the lung was deflated, multiple small, bluish, pulsating lesions on the surface of the lower lobe as well as a lesser number of similar lesions in the upper lobe became visible (Fig. 4). A filamentous capillary network of vessels containing bright red blood was observed on the visceral and parietal pleural surface. At least fifteen dark bluish telangiectatic areas were discernible in the lower and upper lobes. The widespread distribution of the lesions and the probability that

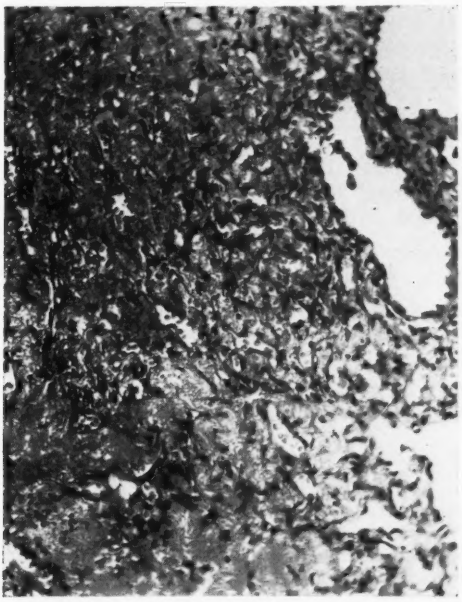


Fig. 5*B*. (For legend, see opposite page.)

the right lung was similarly affected precluded surgical cure. A specimen for biopsy was obtained from the lateral basal segment of the left lower lobe, which contained some of the larger of the tiny aneurysms. The patient was discharged from the hospital on Sept. 29, 1953, after an uneventful recovery.

The largest gross lesions in the specimen of lung measured approximately 3 mm. in diameter. Microscopic sections of the specimen revealed a mildly thickened pleura, together with foci of angiomatous proliferation. In one area there was pronounced thickening of the pleura with necrosis and hyaline change about the periphery involving primarily thick-walled vascular channels. The pulmonary parenchyma, in its deeper portions, exhibited the usual microscopic appearance, and the branches of the pulmonary tree were normal. The angiomatous process appeared to be of mature type (Fig. 5, *A* and *B*).*

*Interpretation of histologic sections was made by Dr. B. L. Newton of the Department of Pathology.

DISCUSSION

The observations in this case indicate that the multiple, minute pulmonary arteriovenous fistulas were a manifestation of the disorder described by Osler,[12] Weber,[19] and Rendu[13] termed "hereditary hemorrhagic telangiectasia." Criteria for the diagnosis of Osler-Weber-Rendu disease include a definite history of heredity, visible telangiectasis with a pathologic distribution, and a tendency toward bleeding from these lesions. The fact that about 40 per cent of patients with pulmonary arteriovenous fistulas have telangiectasis in other parts of the body strongly suggests that the pulmonary lesions represent merely a localized manifestation of a generalized capillary abnormality. In many reported cases, attention has been called to the fact that the pulmonary lesion appeared to be a manifestation of hereditary hemorrhagic telangiectasia.[8, 10, 14] Multiple, minute pulmonary arterial fistulas may shunt enough blood, an estimated 30 per cent of the total circulation,[20] away from the pulmonary alveoli and capillary network to produce cyanosis, even though no lesion may be visible radiographically. Brink[1] reported a case of a patient 19 years of age with cutaneous and abdominal visceral hemangiomas proved by laparotomy, in whom there was a familial history of telangiectasia. Although that patient was cyanotic, had clubbed fingers, and had an arterial oxygen saturation of only 70 per cent, the pulmonary lesions were not demonstrable radiographically, including angiocardiography. Exploratory thoracotomy was not carried out. In other reported cases of patients with generalized telangiectasia, cyanosis has been attributed to peripheral rather than central vascular factors.[4, 9] In these instances the coexistence of pulmonary arteriovenous fistula was not strongly considered or else was felt to be of academic interest only, and thoracotomy was not recommended. In the case herein reported, there were multiple telangiectases over the surface of the body, varying in size from pin point to 2 cm. in diameter, and plethora was probably attributable to cutaneous capillary abnormalities as well as to cyanosis and polycythemia.

A definite familial history of hemangiomas, as existed in our case, has been found in about 15 per cent of reported cases of pulmonary arteriovenous fistulas, and in three instances the pulmonary lesions have been discovered in siblings.[6, 7, 10]

Absence of bleeding manifestations, characteristic of Osler-Weber-Rendu disease, in our patient does not exclude the case as an example of hereditary telangiectasia since hemorrhagic phenomena may not appear until the third or fourth decade of life, or even later. It is entirely possible, therefore, that our patient may subsequently exhibit a bleeding tendency. Typical manifestations include hemoptysis, hematemesis, melena, hematuria, and cerebrovascular accidents. At autopsy, telangiectases have been found in the skin, nose, mouth, pharynx, larynx, trachea, stomach, and duodenum. The tendency toward chronic bleeding in these cases may lead to severe secondary anemia.

In the usual case of pulmonary arteriovenous aneurysm, the diagnosis may be strongly suggested by the standard roentgenographic techniques and

further confirmed by angiocardiography. Whereas the diagnosis of pulmonary arteriovenous fistula can usually be readily established by these techniques, in the exceptional case such as that reported here, multiple, minute lesions may not be sufficiently well visualized by contrast medium in the pulmonary artery to establish the diagnosis unequivocally. In such instances, limited thoracotomy with exploration of the lung and excision of a specimen for biopsy is justifiable. Because the diagnosis in our case was more easily and completely established by thoracotomy, cardiac catheterization was unnecessary, although it would have provided interesting data for following the physiologic changes, particularly in cardiac output, as the patient grows older and cyanosis increases.

The pathologic findings on biopsy in this case were particularly striking. Microscopically, each lesion exhibited the characteristic appearance of pulmonary arteriovenous fistula, as described by Yater and his associates,[22] namely, the presence of a distended, thin-walled afferent artery, distended afferent veins, and an intervening vascular sac consisting of distended vessels. Although these pulmonary lesions have been called pulmonary angiomas or cavernous hemangiomas of the lung, in most instances the histologic findings have been similar to those associated with acquired arteriovenous fistula in the systemic circulation. Biopsy in this patient offered the additional advantage of permitting histologic study of a generalized angiomatous change occurring in the pulmonary capillary system and possibly elucidating the pathogenesis of pulmonary arteriovenous fistulas. According to Yater and his associates, the vascular components of the lesion apparently gradually become more dilated, and the degenerative changes which may occur contribute to formation of even more intercommunications between pulmonary arterioles and venules, with resultant occasional rupture and hemorrhage into the lungs or pleural cavity. Thus, this case would appear to provide a unique opportunity to observe the progress of the pulmonary telangiectases clinically and radiographically. It is planned to review the case several years hence and to study more pulmonary tissue, if possible, in an attempt to establish progression or regression of the pathologic process revealed by the initial biopsy.

SUMMARY

A case of moderate cyanosis with hereditary telangiectasis in a girl 7 years of age is reported. It is believed to be the first case of multiple pulmonary telangiectasia actually proved by thoracotomy and pulmonary biopsy. Moreover, it should provide an opportunity for study of the pathogenesis of pulmonary hemangioma. The usefulness of pulmonary biopsy is emphasized as a means of elucidating the nature of obscure diseases of the lung.

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ONE-STAGE THORACOPLASTY USING THE TRAPP ADHESIVE HEMICAST

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IN ALASKA, hospital beds for the treatment of tuberculosis are extremely inadequate to meet existing needs. The vast majority of patients admitted for tuberculosis have been on the waiting list for two years or longer. Only two hospitals in Alaska offer major surgical treatment for tuberculosis. Under such conditions, any collapse procedure which can speed up the discharge of arrested cases without serious increase in mortality and morbidity deserves adequate trial and evaluation.

In November, 1951, Trapp presented his original work on a thoracoplasty completed in one stage, with stabilization of the chest wall against paradoxical respiratory movements by use of an adhesive plaster cast. He suggested that the procedure might be used routinely, eliminating one or more stages of the Alexander technique. Since that time, ninety-nine consecutive graded thoracoplasties for collapse of tuberculous lung tissue have been carried out on Eskimo, Indian, and Aleut patients at the Mt. Edgecumbe Hospital as a single-stage procedure with no operative deaths. In forty-one of these cases, the Trapp adhesive hemicast was used to eliminate motion of the flail chest wall with satisfactory results.

SURGICAL TECHNIQUE

The thoracoplasties of from four to ten ribs were carried out through a parascapular incision with the patient in the lateral recumbent position. Anesthesia was intravenous Pentothal Sodium supplemented with nitrous oxide and oxygen given through an endotracheal tube in a closed system. Bleeding was controlled by clamping and electrocoagulation. Skin towels were applied and the scapula was retracted upward with a Tuffier self-retaining rib retractor. Serratus anterior muscle attachments to the second rib were severed. The ribs were removed subperiosteally in graded segments beginning with the third or fourth and working upward. The posterior stump of the first rib was left at the level of the vertebral transverse process, while the succeeding posterior stumps were taken to include the respective transverse processes. After completion of the upper ribs and control of bleeding, a hot laparotomy pack was inserted in the collapsed area and the self-retaining retractor removed. The remaining rib segments were then removed from above downward to the desired level, taking transverse processes with the usual exception of the lowest segment. Bleeding from intercostal vessels was controlled either by ligature or electrocoagulation,

From the Alaska Native Service Hospital, Mt. Edgecumbe, Alaska.
Read (by title) at the Thirty-third Annual Meeting of The American Association for Thoracic Surgery, San Francisco, Calif., March 27, 28, and 30, 1953.

TABLE I. THORACOPLASTIES STABILIZED BY TRAPP HEMICAST

CASE NO.	AGE	SEX	DATE OF SURGERY	SIDE	NUMBER OF RIBS	PINTS BLOOD	SHOCK THERAPY (HR.)	FREQUENCY OF HYPOS. (HR.)	COMMENTS
1 JA	21	M	11/29/51	R	6	3	7	3	Complained of heat from setting plaster; atelectasis relieved by tracheal aspiration
2 RP	19	M	12/13/51	L	6	3	2	4-8	
3 EM	38	M	12/13/51	L	8	4	5½	10	
4 ME	21	F	12/18/51	R	5	2	7	3	
5 LC	39	F	12/20/51	L	8	3	4½	3-4	
6 CT	26	F	1/ 3/52	L	6	3	9	4	Partial scapulectomy
7 MT	28	F	1/24/52	R	10	3	2½	4-7	
8 AM	28	F	1/24/52	R	6	3	6	6	
9 SA	23	M	1/31/52	L	8	2	3¼	3½-7	
10 IE	31	M	2/ 7/52	L	6	2	2	4	
11 GA	32	M	2/ 7/52	R	6	2	14	3-7	Pleural tear sutured. Thoracenteses 4th and 7th days. Hemiplegia 32nd day and expired 36th day. Hemorrhage into right cerebral ventricle
12 MY	49	F	2/14/52	L	9	2	9	3-4	One water seal drain left in subscapular space 5 days because of large pleural tear
13 MC	20	F	2/14/52	L	7	2	5	4-9	
14 BB	13	M	2/26/52	L	6	1½	6¾	3-6	Five-rib thoracoplasty on right side 4/15/52
15 JS	27	M	2/28/52	R	8	3	5¼	5½-7½	Digitalized on 4th postoperative day for persisting tachycardia
16 TA	30	M	2/28/52	R	6	2	3½	3¼-13½	
17 RT	55	F	3/ 6/52	R	6	3	7¾	5-14	
18 JP	19	M	3/27/52	R	5	1	3	3½-6½	Right pneumonectomy 2/18/53
19 WW	24	M	4/ 9/52	L	7	2	2½	4-9	
20 JO	26	M	4/10/52	R	8	2	5	3½-8	Right thoracenteses 4/14 and 4/15; cast removed 4/15 and reapplied
21 AY	21	M	4/14/52	R	6	2	5	4	Pleural tear sutured. No thoracentesis
22 EB	17	M	4/16/52	L	6	2	2½	5	Right 5-rib thoracoplasty on 6/25/52
23 BG	39	F	6/10/52	R	7	2	43¼	5-6½	Sudden shock 27 hr. postop. Thought to have pulmonary embolus. Coughed up plug of inspissated mucus on 6/18/52
24 FS	37	F	6/19/52	L	7	2	12	4-9	Pregnancy in 2nd trimester. Normal delivery 11/14/52
25 DE	44	M	6/26/52	R	6	2	6	5	
26 GB	17	F	7/ 2/52	R	6	2	2	4-12	Partial scapulectomy
27 LB	20	M	7/ 8/52	L	6	2	3¾	3¾-5¼	Partial scapulectomy
28 JC	39	M	8/12/52	L	8	2	4	3¾-5½	Thoracentesis 8/18

TABLE I—CONT'D

CASE NO.	AGE	SEX	DATE OF SURGERY	SIDE	NUMBER OF RIBS	PINTS BLOOD	SHOCK THERAPY (HR.)	FREQUENCY OF HYPOS. (HR.)	COMMENTS
29 MB	41	F	8/18/52	L	7	2	3	3¾-5½	
30 IB	19	F	8/20/52	R	5	2	2	3½-6	Left 4-rib thoracoplasty 10/29/52
31 GY	42	M	8/27/52	L	8	2	3¾	3½-5	
32 JW	55	M	8/28/52	L	5	2	2½	4-7	
33 CH	24	M	9/24/52	R	6	2	13	4-5	
34 EA	39	M	10/ 2/52	R	5	2	7	6-8	Pleural tear sutured. Thoracenteses on 10/4 and 10/6. Left 4-rib thoracoplasty on 1/8/53
35 OH	23	M	10/22/52	R	6	2	14	5¼-10	
36 WC	33	F	1/14/53	L	6	2	5	6½-10	Partial scapulectomy. Attempted thoracentesis on 1/26 yielded no fluid
37 WN	15	M	1/21/53	L	7	2	2½	4½-5	Partial scapulectomy
38 RK	21	M	1/21/53	L	6	2	3	5½-9	Thoracentesis 1/26 with cast removed
39 KE	23	F	1/27/53	R	7	3	5¾	4¾-6	Partial scapulectomy. Thoracenteses 2/2 and 2/4 with cast removed on 2/2/53
40 OM	21	F	1/28/53	R	6	2	5	4½-11½	Partial scapulectomy. Cast removed on 2/3 because of pressure at edge
41 WN	62	M	2/ 4/53	R	6	2	2	5¾-10½	

and bleeding from the rib stumps by small oxycellulose packs. The scapula was brought down and tested for impingement on the remaining ribs and, wherever indicated, a partial scapulectomy was carried out. A suction catheter was left in the subscapular space during most of the closure to remove trapped air.

Closure was effected by continuous No. 1 chromic to the muscles in two layers, continuous No. 1 plain catgut to the subcutaneous tissues, and, after removal of the catheter, continuous No. 1 silk to the skin edges. A sterile gauze dressing, 4 inches wide and slightly longer than the wound, was applied and the surrounding skin of the entire hemithorax was painted with tincture of benzoin compound. Where only four or five ribs were removed, the motion of the chest wall was evaluated to determine whether or not a plaster cast was indicated. Where paradoxical movement of the chest wall was considered slight and of little consequence, a tight adhesive dressing was applied with padding in the infraclavicular region. In the more extensive procedures and where more support was needed, the dressing and skin of the entire hemithorax was encased in a layer of elastoplast adhesive. Four or five orthopedic plaster of Paris splints, 6 inches wide, were applied in a U-shaped manner with the ends extending into the infraclavicular fossa and interscapular area and dipping low in the axilla to prevent interference with circulation in the arm. The splints were well molded in place to ensure a solid cast and firm adherence to the mesh of the elastoplast. The patient's hips were supported off the table with a pillow while

the entire chest and cast was wrapped with three-inch elastic bandages. The patient was then returned to his room and placed on his operated side with 10 inch elevation of the foot of the bed until the blood pressure had remained stable with the systolic pressure above 100 mm. Hg for at least two hours. Intranasal oxygen and intravenous blood and fluids were also given during this time. The cast was left in place for five to twelve days.

DISCUSSION

Prior to the development of the modern thoracoplasty, paradoxical respiratory movement in the flail chest wall had caused serious postoperative shock with a high mortality rate. This hazard was effectively controlled when the procedure was broken down into several stages of two or three ribs each. The satisfactory completion of ninety-nine consecutive thoracoplasties in single stages was made possible only by the availability of an effective method of controlling paradoxical motion.

The forty-one cases which required the Trapp adhesive hemicast to stabilize the chest wall are evaluated in Table I. The ages of this group ranged from 13 to 62 years with an average age of 30.5 years. There were sixteen women and twenty-five men patients. Twenty were operated on the left side and twenty-one on the right. The number of rib segments taken at the single procedure varied from five to ten, with an average of six and one-half. Postoperative shock was unusually severe in four cases (1, 15, 23, and 35). Two of these patients had postoperative atelectasis, one relieved by tracheal aspiration and the other misdiagnosed as pulmonary infarction until she coughed up a plug of inspissated mucus on the eighth postoperative day. One patient was digitalized on the fourth postoperative day because of a persisting rapid, feeble pulse. There were no preoperative conditions in these cases which might have suggested the preference of a staged procedure. All cases survived the immediate postoperative period and only one death has occurred (No. 11), and this was due to a cerebrovascular accident on the thirty-second postoperative day with death on the thirty-sixth day. This patient's condition was considered satisfactory up to the onset of hemiplegia and the death is believed not to be associated with the technique of thoracoplasty. The average time of elevation of the foot of the patient's bed after surgery was six and one-quarter hours.

Blood replacement varied from 1 to 4 pints, with an average of 2.3 pints per patient.

An attempt was made to estimate postoperative pain according to the period of pain relief between hypodermics of Pantopon or Demerol during the first forty-eight hours postoperatively. This appears to be comparable to that in our previous first stage thoracoplasties with the removal of three ribs. Many patients were found to be remarkably free of severe postoperative pain and these cases were for the most part among the men with little subcutaneous fat. Women with large breasts and with a thick adipose layer under the skin were apt to complain of pressure at the edge of the cast. In one case the complaint was

so bitter that the cast was removed on the fifth day and a new cast applied with satisfactory results. In the other cases where the cast was removed on the fifth and sixth day, pain was markedly increased in spite of pressure dressings.

In a series of thirty-five first-stage thoracoplasties done between March and November, 1951, using similar anesthetic and operating technique except that only segments of ribs 1, 2, and 3 were resected, the duration of administration of anesthesia averaged one hour and forty minutes. In forty-one cases stabilized by the Trapp hemicast, an average of six and one-half ribs were taken with an average anesthesia time of one hour and forty-nine minutes. In seven of these cases, a partial scapulectomy was also done.

Tearing of the pleura at surgery was recognized and sutured in three cases. Thoracenteses were done in the immediate postoperative period on six patients. In three of these, the cast was removed on the fifth or sixth day to permit thoracentesis. In the others it was carried out close to the edge of the cast with slight trimming of the cast in one case.

Comparison of recent x-rays on the first twenty of these cases with those of the preceding twenty staged thoracoplasties shows no significant difference in postoperative scoliosis. There appears to be a slight improvement in the amount of collapse in the one-stage thoracoplasties although methods of measurement were crude.

The Trapp adhesive hemicast was also used on two patients with left pneumonectomies and simultaneous four- and five-rib thoracoplasties. In one of these who had an empyema and bronchopleural fistula, an intercostal drain with strong suction was maintained below the edge of the cast for four days until drainage ceased. Recovery was uneventful in both cases. In a third case, in which an empyema space was opened with partial decortication of the lung and resection of the overlying segments of ribs 7, 8, 9, and 10 to permit closure of the space, an adhesive cast was used to stabilize the chest wall. Two drains were left in the lower limits of the empyema space and connected to a thermal suction pump at –90 mm. Hg for eight days and then removed along with the cast. The empyema space remained closed satisfactorily and the patient was remarkably free of postoperative discomfort.

The success of the Trapp adhesive hemicast in this series suggests that the technique might well be adapted to treatment of crushing injuries to the chest and in multiple rib fractures.

CONCLUSION

Routine use of the single-stage thoracoplasty, stabilized in selected cases by the Trapp adhesive hemicast, has been found satisfactory in treating Alaska natives. The advantages include: the economy of operating-room service for each patient treated; the economy of total blood replacement; increased turnover of hospital beds; and, especially, the greater ease with which patients can accept a single operation rather than a series of operations.

SUMMARY

Ninety-nine consecutive thoracoplasties have been completed in single stages with no operative deaths. In forty-one of these, paradoxical motion of the chest

wall was controlled satisfactorily by the Trapp adhesive hemicast. Complications were treated without serious difficulty. Slight increase in morbidity was well justified by the increased rate of definitive treatment and the reduced mental trauma of the individual patient.

REFERENCE

Trapp, W. D.: One-Stage Thoracoplasty Using an Adhesive Hemicast, Dis. of Chest 23: 428, 1953.

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